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The effect of Baduanjin exercise on cognitive function in elderly people: A systematic review based on near-infrared spectroscopy technology

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Abstract. To systematically evaluate the application of near-infrared spectroscopy technology in the study of the effect of Baduanjin exercise on cognitive function in elderly people. Relevant literature was retrieved from PubMed, Web of Science core database, ScienceDirect, Wanfang, VIP, and CNKI from 2014 to June 2023, and relevant data were extracted. A total of 1 valid literature was obtained, published in 2022, sourced from the medical journal "FRONTIERS IN PUBLIC HEALTH", with an impact factor of 6.46. This journal belongs to JCR Q1 area, and the SCI basic version of the Chinese Academy of Sciences is in the Q3 area of medicine. The inclusion criteria for the subjects of this study were age ≥ 60 years, experience of Baduanjin exercise for ≥ 3 years, and MMSE score ≥ 24 points. This study, based on functional near-infrared spectroscopy technology, explores the effects of Baduanjin imagery and Baduanjin exercise on cognitive function in elderly people. Baduanjin exercise can increase brain connectivity, improve brain structural connections, and enhance brain function in elderly people. These three factors are also the main reasons for Baduanjin exercise to promote the improvement of cognitive function, including increasing brain gray matter volume, brain functional area connections, etc. Baduanjin exercise can improve specific cognitive functions by increasing gray matter volume. Baduanjin exercise can regulate the functional connections of the cognitive control network in elderly people and improve their memory.

Keywords: cognition, brain function, systematic review, functional near-infrared spectroscopy technology

1. Introduction

By the end of 2021, the population of elderly people aged 60 and above in China had reached 267 million, accounting for 18.9% of the total population. It is estimated that around 2035, the proportion of elderly people aged 60 and above in the total population will exceed 30%, marking China's entry into a stage of severe aging. With aging, most elderly individuals experience deterioration in cognitive function, and some may even develop cognitive impairments. Cognitive impairment, also known as neurocognitive disorders (such as mild cognitive impairment, dementia, Alzheimer's disease, etc.), typically affects abilities such as learning, memory, language, attention, etc. Therefore, it is urgent to prevent age-related cognitive decline in middle-aged and elderly populations.

Numerous studies have demonstrated the positive effects of physical exercise on the cognitive and motor functions of elderly individuals [1]. Baduanjin, as a traditional Chinese fitness exercise [2], emphasizes the harmonious integration of symmetrical body postures, combined with meditation and breathing techniques to strengthen the body and focus attention [3]. Such characteristics are conducive to improving the physical and mental health of elderly individuals. As a form of physical exercise, Baduanjin can provide moderate-intensity aerobic training, which, by stimulating neural physiological pathways, is beneficial for improving cognitive function. Research has confirmed that Baduanjin exercise is suitable for improving muscle strength [4] and enhancing sleep quality [5], as well as for improving cognitive function [6].

In addition to traditional exercise interventions for improving physical and mental health, another widely studied and applied method is motor imagery training, which is characterized by high safety and strong operability [7]. As a form of psychological intervention, motor imagery does not require actual movement; rather, it involves mentally simulating movements, reflecting the brain's perception of movement [8], and can be applied in situations where physical movement is inconvenient or space is limited. Previous studies have shown that motor imagery shares neurophysiological similarities with actual movement. For example, Jacobson [9] suggested that individuals exhibit peripheral physiological effects similar to actual movement during motor imagery,

such as action potentials and heart rate. The motor simulation theory proposed by Jeannerod [8] suggests that in terms of neural circuit planning and involvement, motor imagery is functionally equivalent to actual movement [10]. This neural similarity has prompted researchers to continuously explore the broader potential applications of motor imagery, such as improving motor functions (e.g., walking speed [10], muscle strength, etc.) or cognitive functions (e.g., attention, working memory, etc.). As a form of motor imagery, Baduanjin imagery should have a similar facilitating effect on improving cognitive decline in the brain.

The prefrontal cortex (PFC) is an important brain region responsible for executive functions, with the dorsolateral prefrontal cortex (DLPFC) and inferior frontal gyrus (IFG) being the main activation areas [11]. They play crucial roles in ensuring attention allocation and enhancing cognitive control, serving as important brain regions in the cerebral cortex involved in meeting and maintaining individual attention demands [12]. Studies have shown that physical exercise increases the oxygen concentration in the left DLPFC [13], and Malouin [14] also found that motor imagery, like actual movement, increases the oxygen concentration in the left DLPFC of participants. Additionally, numerous neuroimaging studies have shown that both physical exercise [15] and motor imagery [16] can activate the IFG. Therefore, to further elucidate the neural mechanisms underlying the improvement of cognitive function by physical exercise and motor imagery, it is necessary to explore the activation effects of motor imagery.

Functional near-infrared spectroscopy (fNIRS) technology is widely used in the field of cognitive neuroscience to measure real-time changes in the concentration of oxygenated hemoglobin in the cerebral cortex, reflecting individual brain activation states [17]. It is an optical neuroimaging technology based on neurovascular coupling and spectroscopy theory, which monitors changes in cerebral oxygenation by spectroscopically determining oxyhemoglobin and deoxyhemoglobin, and quantitatively describes light transmission in tissues to study the neural mechanisms involved in cognitive activities. Previous studies have shown that fNIRS can be used to evaluate the cerebral hemodynamic characteristics of healthy and impaired populations [18], such as those with mild cognitive impairment, Alzheimer's disease, depression, stroke, etc., which is beneficial for early detection of cognitive impairment and monitoring rehabilitation effects. In addition, fNIRS has advantages such as portability, safety, low cost, and high temporal resolution [19], making it highly suitable for studying the effects of exercise on cognitive function and cerebral hemodynamics. These advantages also make fNIRS have the potential for extensive implementation in research on the brain mechanisms underlying the effects of exercise on cognitive function in elderly individuals [20]. Furthermore, studies related to motor imagery and exercise mainly use cognitive behavioral task assessments to evaluate the effects of cognitive function [21], thus necessitating further exploration of their neural mechanisms using neuroimaging techniques.

Therefore, this study systematically searched and collated the practical application of fNIRS technology in assessing the effects of Baduanjin exercise on cognitive function in elderly individuals, aiming to further investigate the impact of Baduanjin exercise on cognitive function in elderly individuals and elucidate its physiological and mechanistic effects.

2. Materials and methods

2.1. General information

A combination of subject terms and free words was used to search three English literature databases (Web of Science core database, ScienceDirect, PubMed) and three Chinese literature databases (VIP, CNKI, Wanfang Database) from 2014 to May 2023.

Chinese search strategy: (Baduanjin OR Traditional Chinese Medicine exercise Baduanjin OR Baduanjin exercise OR Health Qigong Baduanjin OR traditional Qigong Baduanjin OR Qigong Baduanjin OR Fitness Qigong Baduanjin OR sitting Baduanjin OR standing Baduanjin OR vertical Baduanjin) AND (cognitive function OR cognitive ability OR memory OR attention OR executive ability OR brain function) AND elderly people

English search strategy: (the elderly OR the older people OR older adults OR the aging people) AND (Baduanjin* OR TCM exercise Baduanjin* OR Baduanjin exercise* OR Health Qigong Baduanjin* OR traditional Qigong Baduanjin* OR Qigong Baduanjin* OR Fitness Qigong Baduanjin* OR sitting Baduanjin* OR standing Baduanjin* OR vertical Baduanjin*) AND (cognitive function OR cognitive ability OR memory OR attention OR executive ability OR brain function)

Table 1. Inclusion and exclusion criteria for literature

Serial No.	Inclusion Criteria	Exclusion Criteria
1	Publication with full accessibility	Repeated reports, literature of poor research quality that cannot be deeply analyzed
2	Only include RCTs on the impact of Baduanjin exercise on cognitive function	Review or commentary articles
3	Topics related to the cognitive function of healthy or diseased elderly people	Data unclear or incomplete, preventing systematic analysis
4	Intervention method is solely Baduanjin exercise	Intervention method involves combined intervention of Baduanjin exercise with other exercises
5	Observation method is functional near-infrared spectroscopy	Unreasonable experimental methods
7	Chinese and English literature available	

2.2. Literature screening and data extraction

Two researchers independently screened the literature and extracted data, including the title, author, publication date, country, journal of publication, research subjects, experimental methods, and research conclusions. Duplicate literature was first excluded, then irrelevant literature was eliminated by reading the titles and abstracts, and finally, each article was read in full to determine whether it should be included. In cases of disagreement, a third party made the judgment. The literature screening process is illustrated in Figure 1.

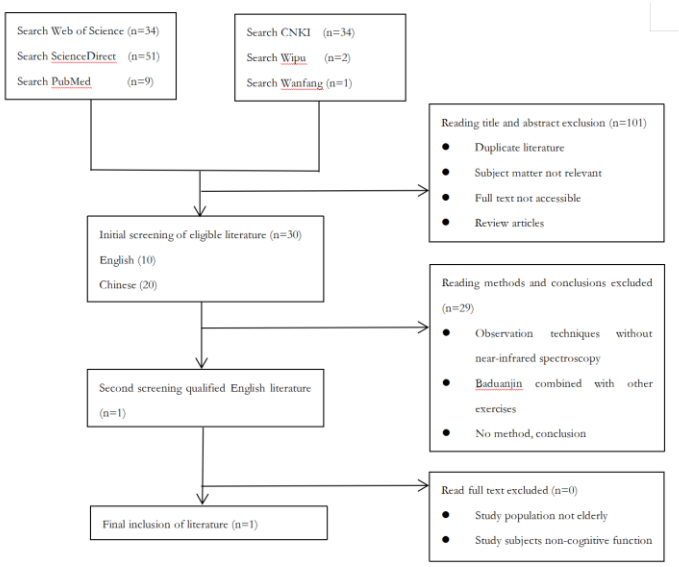

Figure 1. PRISMA flowchart

3. Results

3.1. General information

After screening, a total of 1 valid literature meeting the research objectives was obtained, published in 2022 in the medical journal "FRONTIERS IN PUBLIC HEALTH" with an impact factor of 6.46. This journal belongs to the JCR Q1 area and the SCI basic version of the Chinese Academy of Sciences in the Q3 area of medicine. The inclusion criteria for the participants in the study were age ≥ 60 years, with a minimum of 3 years of experience in Baduanjin exercise, and MMSE score ≥ 24 points. This study, based on functional near-infrared spectroscopy technology, explored the effects of Baduanjin imagery and Baduanjin exercise on the cognitive function of elderly individuals separately, as well as whether Baduanjin imagery has the same effect as actual exercise, and investigated the brain oxygen mechanism of Baduanjin imagery in improving cognitive function, providing practical evidence for enhancing cognitive function in elderly individuals, as shown in Table 2.

Table 2. Analysis of Valid Literature

Included Literature	Country	Research Subjects	Intervention Strategies	Evaluation Methods	Research Results	Limitations
Yao L, Sun G, Wang J, et al. (2022)	China	Healthy elderly individuals	Baduanjin imagery Baduanjin exercise Reading neutral materials	Neurophysiological indicators (throughout the experiment): Changes in blood oxygen in the prefrontal cortex (PFC) Behavioral indicators (cognitive tasks): Accuracy and reaction time of the Stroop test	Both Baduanjin imagery and Baduanjin exercise significantly reduced the reaction time of participants in completing inhibitory control tasks, improving cognitive response speed.	Only monitored changes in oxygenated hemoglobin in the prefrontal cortex (PFC), without exploring the effects of Baduanjin imagery on oxygen concentration in other brain regions.

Table 2. (continued).

	Assessment indicators: a. Mini-Mental State Examination (MMSE) b. Physical Activity Rating Scale-3 (PARS-3) c. Movement Imagery Questionnaire-Revised (MIQ-R)	In the post-test cognitive state, both Baduanjin imagery and Baduanjin exercise significantly increased the concentration of oxygenated hemoglobin (oxy-Hb) in the left dorsolateral prefrontal cortex (DLPFC) of the subjects. In the post-test cognitive state, Baduanjin imagery significantly increased the concentration of oxy-Hb in the right inferior frontal gyrus (IFG) of the subjects.	The intervention in this study used visual-motor imagery, which may need further refinement depending on perspective and medium; the brain activation effects of different types of motor imagery still need further investigation. Lack of short-separation channels in this study may cause interference with superficial cortical blood flow. Only Baduanjin was used as an intervention in this study, and it was found that there were similar brain activation effects between elderly individuals' motor imagery and actual exercise. Future research can further examine the effects of motor imagery training on other traditional movements.

3.2. Baduanjin exercise and motor imagery

Motor imagery is a psychological intervention technique that involves mentally rehearsing motor activities without any physical movement. Working memory is a memory system that temporarily stores and manipulates language and image information, playing a significant role in complex cognitive tasks such as language comprehension, learning, and reasoning. As a dynamic simulation process, motor imagery training temporarily stores given motor representations in working memory, inhibiting overt behavioral performance. For elderly individuals with severe motor function impairment, motor imagery is an important intervention method that can promote both motor and cognitive function recovery. Existing research has shown that motor imagery training not only significantly enhances the working memory of elderly individuals but also improves their learning ability and has a significant impact on their inhibition function. The motor simulation theory suggests that motor imagery and actual actions share similar psychological representations and mechanisms, activating similar neural pathways and cortical networks as those induced by actual actions. However, some studies have also shown differences in brain region activation and brain network connectivity between motor imagery and real movement. Therefore, further research is needed to investigate the differences in brain region activation between motor imagery and motor execution and to validate the neural basis of motor imagery. When not limiting the observation technique to functional near-infrared spectroscopy, most of the research subjects in the literature screening process are elderly individuals, including healthy individuals, dementia patients, and Alzheimer's disease patients [22]. The research content includes overall cognitive function [23], memory [24], attention [25], language [26], and executive function [26], among others. The assessment methods include functional magnetic resonance imaging [27], behavioral experiments [28], etc. Statistical analyses such as analysis of variance, regression analysis, and various model specifications were used to analyze the data [23].

3.3. Mechanisms of Baduanjin exercise on cognitive function

As the purpose of this study is to explore the application of functional near-infrared spectroscopy (fNIRS) in investigating the effects of Baduanjin exercise on the cognitive brain function of elderly individuals, the focus on elucidating the mechanisms of Baduanjin exercise and motor imagery on cognitive function primarily centers on brain mechanisms.

Improvements in brain structure and function are the main reasons for Baduanjin exercise promoting cognitive function enhancement, including increased gray matter volume (GMV) of the brain and functional connectivity in brain regions.

Baduanjin exercise can improve specific cognitive functions by increasing gray matter volume. Studies have shown that Baduanjin exercise increases the gray matter volume (GMV) of the medial temporal lobe (MTL), insula, and caudate nucleus in elderly individuals, which are positively correlated with memory quotient (MQ) and visual reproduction scores [29]. The significant improvement in visual reproduction scores suggests that Baduanjin exercise can effectively improve spatial-related memory function.

Baduanjin exercise can regulate the functional connectivity of the cognitive control network in elderly individuals to improve memory. After Baduanjin exercise, the resting-state functional connectivity (rsFC) between the bilateral dorsolateral prefrontal cortex (DLPFC) and the left caudate nucleus/insula significantly decreases. The improvement in cognitive function is negatively correlated with the resting-state functional connectivity (rsFC) between the bilateral DLPFC and the left caudate nucleus, most of which are observed using resting-state functional magnetic resonance imaging (rs-fMRI).

Baduanjin exercise can significantly improve the overall cognitive function of patients with mild cognitive impairment (MCI) through changes in functional connectivity areas. Li Moyi et al. [27] demonstrated in their experiment that six months of Baduanjin exercise significantly improved the overall cognitive function of patients with MCI, and the intervention effect may be superior to brisk walking exercise. Resting-state functional magnetic resonance imaging (rs-fMRI) results showed that Baduanjin exercise could significantly enhance the functional activity of the bilateral lentiform nucleus, left hippocampus, left inferior frontal gyrus (IFG), right superior frontal gyrus (SFG), and left middle temporal gyrus in patients with mild cognitive impairment. Xia Rui et al. [25] found that after six months of Baduanjin exercise, changes occurred in the functional connectivity of the dorsal attention network in elderly individuals with mild cognitive impairment, including the right middle temporal gyrus, right fusiform gyrus, right precuneus, and right central sulcus, as observed through rs-fMRI.

While reviewing the selected literature content, the author found that the study aimed to measure the effect of Baduanjin exercise imagery on the activity of neurons in the left dorsolateral prefrontal cortex (DLPFC) and right IFG using functional near-infrared spectroscopy (fNIRS) during elderly individuals' inhibitory control tasks. This study utilized fNIRS to monitor changes in PFC oxygen levels in elderly individuals before, during, and after intervention, exploring whether Baduanjin exercise imagery has the same effect as actual exercise and investigating the brain oxygen mechanism underlying the improvement of cognitive function by Baduanjin exercise imagery. The study established Baduanjin exercise imagery (exercise) group, Baduanjin exercise group, and control group and proposed the following hypotheses: (1) Baduanjin exercise imagery improves cognitive function in elderly individuals, as reflected in Stroop task reaction time; (2) Baduanjin exercise improves cognitive function in elderly individuals, as reflected in Stroop task reaction time; (3) Baduanjin exercise imagery practice increases the concentration of oxygenated hemoglobin in the left DLPFC and right IFG during inhibition tasks; (4) Baduanjin exercise increases the concentration of oxygenated hemoglobin in the left DLPFC and right IFG during inhibition control tasks. [30] The results indicated that, in the post-test cognitive state, both Baduanjin exercise imagery and Baduanjin exercise significantly increased the concentration of oxygenated hemoglobin (oxy-Hb) in the left dorsolateral prefrontal cortex (DLPFC) of the subjects. This result is consistent with previous related studies. Jiang et al. [31] found in their study on the effect of Baduanjin exercise on the brain function of elderly individuals that those who practiced Baduanjin exercise long-term had greater activation in the prefrontal cortex and higher oxygen concentration. Additionally, Zheng et al. [32] discovered through fMRI that Baduanjin exercise improved cerebral blood flow changes in relevant brain areas of elderly individuals with cognitive impairment. Their study indicated that Baduanjin exercise improved the cerebral blood flow levels in brain areas related to cognitive function in elderly individuals [33]. Similarly, this study found that the concentration of oxy-Hb in the left DLPFC of elderly individuals increased after Baduanjin exercise, suggesting changes in brain function caused by Baduanjin exercise in elderly individuals, consistent with the conclusions of the aforementioned studies.

Another conclusion is that, in the post-test cognitive state, Baduanjin exercise imagery also significantly increased the concentration of oxygenated hemoglobin (oxy-Hb) in the right inferior frontal gyrus (IFG) of the subjects. fNIRS results showed that Baduanjin imagery successfully activated the neurons in the left dorsolateral prefrontal cortex (DLPFC) of elderly individuals when completing cognitive tasks, leading to an increase in oxy-Hb in this brain area. Since an increase in oxy-Hb concentration indicates enhanced cortical activation, Baduanjin exercise imagery training enhanced activation in the left DLPFC during inhibitory control tasks. Motor imagery has a neural basis extremely similar to actual movement, activating the frontal and parietal lobes [34]. Zhang [35] and Kotegawa [36] found that motor imagery significantly increased PFC oxygen levels in subjects, exerting a certain activation effect on the DLPFC. This study demonstrated changes in oxy-Hb concentration in the left DLPFC induced by Baduanjin exercise imagery, which is beneficial for improving the brain function of elderly individuals in cognitive tasks, further supporting previous research on motor imagery [36]. Additionally, the results demonstrated that Baduanjin imagery activated the right IFG, supporting previous studies [37]. The IFG is part of the mirror neuron system and may play an important role in motor imagery [37]. Studies have shown that motor imagery is associated with activation of the mirror neuron system [38], which can

alter the function of cortical areas [39]. This may explain why the concentration of oxy-Hb increased in the right IFG of elderly individuals in the post-test tasks after Baduanjin imagery.

3.4. Effects of Baduanjin exercise on cognitive function in older adults

The dorsolateral prefrontal cortex (DLPFC) and inferior frontal gyrus (IFG) are central regions involved in higher cognitive activities such as attention [40], working memory [41], and cognitive control [42]. Activation in these areas is crucial for the cognitive brain network and serves as the neural basis for enhancing inhibition and control abilities. The potential mechanism of Baduanjin exercise imagery and Baduanjin exercise may involve the activation of the left DLPFC and right IFG. We observed that the control group exhibited a decrease in oxygenation during the post-test tasks. This may be due to a pause in neurovascular coupling. Cognitive fatigue resulting from continuous completion of cognitive tasks can lead to a pause in neurovascular coupling in elderly individuals [43], which may result in decreased neuronal discharge frequency and reduced blood flow, manifested as a decrease in oxy-Hb during post-test tasks. In contrast, intervention with Baduanjin exercise imagery and exercise activated neurons in elderly individuals, increasing oxygenation in brain regions during post-test tasks, highlighting the positive effects of Baduanjin imagery and exercise.

Our study suggests that Baduanjin exercise imagery training can improve cognitive function in older adults similar to actual exercise, highlighting the positive role of motor imagery. In the past, motor imagery has been mainly used to enhance skill learning and physical performance, primarily targeting adolescents and healthy adults. However, as research progresses, motor imagery is gradually becoming a new non-physical means of improving the physical and mental health of older adults [44].

With the widespread popularity of Baduanjin exercise, imagery training of Baduanjin has more advantages in application. For example: (1) Compared with traditional sports imagery training, Baduanjin exercise imagery has unique cultural components, making exercise less dull and more attractive; (2) Baduanjin exercise consists of only 8 simple movements, making it widely accessible. Therefore, Baduanjin imagery has the advantage of being simple and easy to learn, facilitating its widespread application; (3) Baduanjin imagery has a positive effect on the recovery of neurological disorders and can improve cognitive rehabilitation outcomes in elderly patients, such as stroke [45] and Parkinson's disease [46]; (4) Against the backdrop of the COVID-19 pandemic, imagery training is not limited by external factors such as venue, equipment, or weather, making it a simple form of home exercise. Watching videos and imagining movements in Baduanjin exercise imagery training can alleviate cognitive decline in the home-bound population and improve cognitive function in this group.

4. Summary

Cognitive function refers to the comprehensive perception of external stimuli by the brain, including processes such as execution, sensation, perception, thinking, attention, learning, memory, judgment, imagination, concepts, and language. Research indicates that regular exercise can stimulate neuronal metabolism in the brain, enhance synaptic plasticity, and improve cognitive function in the elderly. Health Qigong Baduanjin is a traditional Chinese exercise for health promotion, characterized by moderate-intensity aerobic exercise that focuses on three aspects: regulating the mind, body, and breath. Through adjustments in attention and breathing, it helps individuals achieve a harmonious state of physical and mental health. Currently, studies on the mechanisms between Baduanjin exercise and cognitive brain function in the elderly primarily employ functional magnetic resonance imaging (fMRI). Generally, functional near-infrared spectroscopy (fNIRS) is less utilized in the field of cognitive motor studies. Through systematic literature review, it was found that only one recent paper in 2022 utilized fNIRS technology to study the relationship between Baduanjin exercise and cognitive brain function in the elderly.

Furthermore, research on cognitive function using fNIRS technology is currently focused only on the field of imagery training in sports, while fMRI covers specific cognitive domains such as memory, attention, and language. fNIRS devices are typically categorized as desktop or portable, with the latter being advantageous due to its portability, non-invasiveness, and ease of operation. Compared to other brain imaging technologies like fMRI and computed tomography scans, fNIRS is more cost-effective. During data collection, assessors only need to attach the collection cap to participants, making it suitable for testing during daily activities or various training interventions. The device is minimally affected by motion interference, sweat, or muscle interactions, ensuring the safety and non-invasiveness of the assessment process. It can rapidly produce high-quality results and has long battery life for continuous monitoring. Additionally, it can be integrated with other devices such as fMRI and electroencephalograms for combined assessments. Further exploration into other cognitive domains is warranted in future research.

In terms of mechanisms of action, Baduanjin exercise may enhance cognitive function by affecting the function of the nervous system, thereby enhancing the neural connections of the hippocampus, frontal lobe, basal ganglia, and related brain regions, improving synaptic plasticity, and increasing the effectiveness of brain neurotrophic factors to enhance cognitive function. After 12 weeks of Baduanjin exercise, there was a significant increase in gray matter volume (GMV) in the left medial temporal lobe (MTL), including the hippocampus, parahippocampal gyrus, and amygdala. The MTL, including the hippocampus and adjacent parahippocampal gyrus, as well as the entorhinal and perirhinal cortices, are crucial for memory processing. Reduced gray matter volume in the MTL may lead to subsequent declines in cognitive abilities and the appearance of mild cognitive impairment, making preservation of GMV crucial for maintaining memory function. The striatum plays a role in motor-related functions, executive functions, working memory, as well as learning associations between stimuli, responses, and outcomes. The striatum may exert its effects on cognitive function through a loop connected to the basal ganglia and a series of non-motor areas of the frontal lobe

associated with cognitive functions. Baduanjin exercise may initially regulate the motor-related networks of the striatum and then strengthen its functional connections with memory-related areas such as the frontal lobe. The insula is a brain structure involved in cognitive, emotional, and regulatory functions, playing a key central role in memory processes [15]. Baduanjin exercise may regulate the resting-state functional connectivity (rsFC) between the cognitive control network (CCN) and the striatum and insula. The CCN, including the frontal-parietal brain areas, is a key regulator of attention-memory interactions, preferentially activated in memory-guided visual attention processing tasks. The dorsolateral prefrontal cortex (DLPFC) is an important region of the CCN that plays a critical role in cognitive control processes. Reduced resting-state connectivity of the DLPFC is associated with improvements in memory and brain metabolism and can serve as a marker for stronger cognitive efficiency in brain regions related to working memory. Compared to the control group, Baduanjin exercise reduced rsFC in the CCN, and the decrease in connectivity was associated with memory function.

In summary, Baduanjin exercise may improve cognitive performance while reducing cognitive control network connectivity, suggesting increased efficiency of the cognitive control system and reduced compensatory overactivation of networks. Substantial evidence suggests that the interaction between the hippocampus and medial prefrontal cortex (mPFC) may play a key role in assimilating new memories into pre-existing knowledge networks and adjusting the integration process of new memories into permanent knowledge stores.

This paper explores the promoting effect of Baduanjin exercise on cognitive function, but existing research needs further improvement. Firstly, there is a lack of studies on the sustained effects of Baduanjin exercise, and follow-up observations on patients are needed to observe the long-term effects of Baduanjin exercise. Secondly, there are some methodological flaws in the trials, and future research can adopt allocation concealment and blinding methods, such as having the researchers analyzing the statistical results unaware of the study protocol. Additionally, reporting patient compliance, adverse reactions, and safety in the study process is important. Moreover, efforts should be made to minimize subject attrition in the study and balance the influence of daily activity factors on the subjects. Finally, research on cognitive function can be further explored by designing experimental tasks using E-Prime tools and combining neuropsychological scale tests with functional magnetic resonance imaging (fMRI) to explore the central neural mechanisms of the effects of Baduanjin exercise on cognitive function.

In summary, most studies show that participation in bilingual training can improve cognitive function in the elderly, enhancing brain functional connections related to memory and executive abilities. However, due to the lack of uniform criteria for study populations and reasonable control conditions, as well as inconsistencies in sample size, gender, cognitive levels of participants, and experimental designs, there is still a need for more clinical evidence of the positive effects of bilingual training on cognitive function in the elderly.

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