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Effect of open and locked exercise on cognitive function in older adults

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Abstract

Objective: The extension of life span and the decrease of fertility rate in the elderly population lead to the increasing aging proportion, and the natural growth of age is accompanied by aging. Cognitive diseases will emerge in large numbers at this stage, affecting the cognitive function of the elderly. Methods: The purpose of this review is to comprehensively explore the effects of open movement and locked exercise on cognitive function in the elderly. It discuss the specific effects and related neurobiological mechanisms of different types of exercise on cognitive function (including attention, memory, executive ability, etc.) in the elderly. Results: Open sports can effectively improve attention, executive function and cognitive flexibility in the elderly, and closed sports can have positive effects on memory and concentration by enhancing brain neuroplasticity and regulating neurotransmitters. Conclusion: although two types of movement on the cognitive function of the elderly has its emphasis, but overall, compared with closed movement, open movement in the elderly specific cognitive function

(such as executive function, inhibitory control, task conversion, etc.) show more prominent effect, and help to reduce the brain caused by the age of atrophy and the risk of neurodegenerative changes.

Key words: open skill exercise; closed skill exercise; cognitive function; the elderly

1 Preface

The global aging phenomenon is intensifying, and the number of elderly people continues to rise, which has become an irreversible trend in the process of world development. According to the United Nations' World Society Report 2023 and related population reports, by 2024, the global proportion of the population aged 65 and over has increased to about 10.3%, almost doubling the [1] from 5.5% in 1974. This proportion is expected to double again to 20.7% by 2074, with the core reason behind the continued advances in medical technology and the declining fertility rate of [2]. Many developed countries already have a higher proportion of the elderly population, while developing countries face the rapid arrival of aging, making these regions less prepared to meet the challenge of aging [3]. The decline of cognitive function (Cognitive Function, CF) and cognitive defects (Cognitive Defect, CD) due to aging are also being valued in [4]. Drop in cognitive function is mainly reflected in early adulthood, the basis of cognitive function in daily life, usually reach the peak, however, as into the middle and late adulthood, these abilities began to gradually decline, especially after the age of 60, decline tends to speed up [5], at the same time a variety of cognitive disease will also appear [6]. Cognitive function refers to the set of mental processes involved in the human brain when processing information, including. Perception, attention, visual and spatial processing, language, memory, executive function, such as [7], among them, the executive function also known as cognitive control, refers to a group of advanced cognitive processes, these processes enable individuals to plan, organize, start and complete tasks, executive function is usually associated with the prefrontal cortex of the brain, involving a variety of mental activity [8]. It also includes short-term memory, inhibitory control, thinking flexibility, inference, planning, and problem solving, etc. According to related studies, aerobic exercise and extensive physical exercise on frontal dominant executive control, conflict resolution and inhibitory control has a positive effect, including the transition between psychological set or task (Shifting), working memory content update and monitoring (Updating), and inhibition of dominant response (inhibition) the organization and action of [9]. Cognitive impairment (Cognitive Impairment, CI) is a common type of disease in the elderly. According to research data, as early as 2002, there were about 5.4 million people in the United States, aged 71 and older (22.2%) suffering from cognitive impairment and were affected by [10]. The absence of corresponding interventions will further evolve into dementia [11]. Scientific research and clinical observations have further revealed that, Mild cognitive impairment (MCI) usually shows a slight decrease in memory, thinking ability or judgment, But these changes have not been severe enough to

affect daily life [12], but, Identification and intervention at this stage appear particularly important, If allowed to develop, Can also cause various diseases in terms of cognitive function, Including vascular dementia (Vascular Dementia), Lewy body dementia (Dementia with Lewy Bodies), and frontotemporal dementia (Frontotemporal Dementia, FTD) class. The clinical symptoms of these diseases are diverse, including memory loss, language impairment, impaired judgment, behavioral mood changes, and [13] such as motor dysfunction. Based on this, studies have found that regular exercise can reduce the risk of dementia and Alzheimer's disease, bring hope for improving cognitive function in the elderly, promote brain vitality, and delay cognitive decline [14]. As early as 2008, the US government issued the US Physical Activity Guidelines [15], which clearly states that all adults should take active physical exercise to significantly reduce the risks and harms of various adverse health conditions. By 2018, through continuous research and update, a new version of the American physical activity guidelines, for the elderly, should be a variety of physical activity, including balance training, aerobic exercise and muscle movement, etc., this will reduce the risk of the elderly and fall, and falls, and to improve dementia, MS, ADHD and Parkinson's cognition also has a great impact on [16]. In addition, appropriate or specific exercise can make the elderly more focused on specific tasks, in the elderly, exercise can also promote the improvement of brain related structure, promote the brain secretion of neurotrophic molecules, such as brain-derived neurotrophic molecules (BDNF), it has a great role to improve the elderly short-term memory [17].

To sum up, exercise helps the elderly in many ways. The elderly'physical exercise can enhance the muscle strength that gradually declines due to age, promote bone health, and then reduce various diseases caused by the decline of muscle strength and weakened bone stability. In addition, regular physical exercise is also a key and effective protective measure to slow down cognitive function decline and prevent dementia in the elderly. [18].

2 Open motion and locked motion

2.1 Introduction of open movement and locked movement

In recent years, more and more research began to explore the form of movement and duration for the influence of cognitive function, a certain physical exercise and physical activity on the brain frontal function produce positive effect, through the executive function, inhibitory control exert positive factors, thus promoting the development of human cognitive function [19]. In order to further understand the internal mechanism of this process, we refined physical exercise according to the different participation environments, divided into open skill exercises (open-skill exercise, OSE) and closed skill exercises (closed-skill exercise, CSE), in order to explore which exercise type will play a better role in human cognitive function [20].

Open movement (OSE) refers to the movement in a relatively complex, changeable and unpredictable environment, this kind of movement participants need to respond quickly according to the real-time situation, adjust their action, strategy and decision, requires participants to have a high degree of flexibility and adaptability, online adjust according to real-time changes (on-line adjustment), namely the movement while according to real-time feedback correction action [21], participants through in the complex and changeable environment allocation attention to deal with different challenges. For example, in football, basketball, tennis, badminton and other sports, participants need to observe the opponent's movements, predict the game to make decisions and action, this type of exercise not only need participants have rich cognitive ability to cope with the complex situation, also need the corresponding load ability and diversified movement coordination skills, in order to in different sports situations can maintain good performance [22]. From the perspective of brain imaging and visual area, open movement requires participants in a short period of time for a large number of complex external information rapid screening, processing and processing, and then make the appropriate response, the brain quickly integrate the information decided his next step, the process involves the perception, attention, memory, decision, and other information processing link, and cycle, as the movement situation real-time update [23]. During open motion, the brain coordinates the activities of different brain regions when processing complex visual, auditory and proprioceptive information to achieve precise control of action and strategy selection [24].

Relatively speaking, locked movement (CSE) is in a relatively stable and predictable environment, according to the established, relatively fixed action norms and procedures to complete the movement, mainly follow the preset action program for action control, is a relatively closed, off-line control (off-line control) mode, in the actual execution is basically in accordance with the established mode, unless unexpected interference, less substantial real-time adjustment in the process of movement. Its movement mode and order usually have clear standards, participants mainly focus on the accuracy and stability of their action, in this mode, participants can according to their own rhythm and plan, such as swimming, running, cycling, etc., this type of project movement mode is relatively single and fixed, participants can according to their own fitness and goals, decide the intensity, time and schedule, do not need to consider the change of the external environment too much, and the requirement of cognitive requirements and decision-making is small [25]. In locked sports, athletes often prestore a relatively fixed set of action programs in the brain. The series of action sequence and posture of walking, jumping, running and other activities are established, relying on accurate extraction and execution of pre-stored action procedures to show the complete performance [26].

2.2 Potential possible mechanisms by which movement affects cognitive function

The gradual growth of age for the elderly cognitive function, which is mainly due to the internal structure of the prefrontal cortex and hippocampus, changes lead to changes in white matter, frontal gray matter atrophy [27] and some forms of neurotransmitter depletion, as well as the frontal striatal system and the medial temporal lobe changes [28]. White matter lesions in the brain and elderly memory decline related [29], studies have observed that the influence of white matter changes on performing tasks, using Stroop interference task, cognitive test, measuring response speed of simple cognitive test study, white matter lesions can affect cognitive function in multiple cognitive domains, such as executive ability and memory ability [30], the elderly in the state of dementia, executive function may also be related to the change of the frontal striatal circuit, and lower executive function will affect memory, because memory activity often need to rely on a controlled process. For the elderly with dementia, the elderly with Alzheimer's disease as the object. we found that the medial temporal lobe of Alzheimer's disease showed significant atrophy, cytopathopathy and decreased cell number, which led to severe memory loss [31]. After insights into the mechanisms that lead to cognitive decline and Alzheimer's memory loss, how exercise exerts positive effects to improve cognitive improvement.

In a clinical trial study, it was found that aerobic exercise helped the frontal, parietal, and cingulate cortex to maintain or even increase [32], which could reduce the adverse effects on cognitive function. On the other hand, scientific research has revealed that in our brains, there is a special substance, called brain-derived neurotrophic factor (BDNF), which is seen as a biomarker with positive effects, especially in cognitive function. BDNF plays a crucial role in the growth, differentiation, and survival of neurons. It not only supports brain plasticity, but also is closely related to learning and memory processes. [33]. However, when a person has a neurodegenerative disease like Alzheimer's disease, they have some negative changes in their brain. Specifically, Alzheimer's disease can cause a reduction in neurotrophic factors in the brain, or an impaired function of these factors, which increases cognitive impairment such as memory loss, distraction, poor thinking, and impaired speech. Therefore, the reduction or impairment of brain-derived neurotrophic factors is considered to be an important cause of cognitive decline in patients with Alzheimer's disease [34]. With increasing age, BDNF shows neuroprotective efficacy, reducing neuronal damage and death caused by oxidative stress, inflammation and other causes, maintaining the functional and structural integrity of neurons in brain areas closely related to cognitive function, and then delaying cognitive decline [35].

In addition, related studies have found that in addition to brain-derived neurotrophic molecules (BDNF) and cognitive function, the abnormal accumulation of amyloid β is considered a landmark feature in the onset of Alzheimer's disease (AD). In the pathology of Alzheimer's disease (AD), the amount of β amyloid β increases significantly, especially in the A β 1-42 subtype, which is more neurotoxic. When

the A β 1 – 42 isoform is deposited in the brain, it directly leads to neuronal damage and death, which is one of the main causes of cognitive decline and memory loss in Alzheimer's disease patients [36]. Further research revealed an encouraging phenomenon that increasing physical exercise reduces the amount of β amyloid β in the brain, showing a significant negative correlation between them [37]. This implies that daily physical exercise helps to reduce the accumulation of neurotoxic peptides that may slow or even prevent the progression of Alzheimer's disease. Thus, physical activity is thought to promote the metabolic renewal of amyloid β and may help to prevent cognitive decline or even partly improve the already impaired cognitive function [38].

3 Effect of open exercise on cognitive function in older adults

According to the foregoing, we will further explore the role of OSE on the cognitive function of the elderly group, including perception, attention, visual and spatial processing, language, memory, executive function, etc.

With executive function as the entry point, executive functions include attention diversion, information update, inhibition, transfer, effective regulation of attention, strategy planning, and fluent expression of language [39]. Related studies show that in the process of movement, cognitive demand may stimulate cognitive growth, related animal experimental model shows that under the condition of environmental enrichment and wheel movement, mouse nerve and cell proliferation stimulation compared to baseline level, and this phenomenon has similar validation in humans, for example, fencing as a representative of open movement, research showed that individuals with fencing experience in inhibitory control, and in the reaction time task performance better [40]. In conclusion, both the complexity of the motor environment conditions and the different requirements of the exercise items have an impact on executive function, further confirming the importance of open exercise for improving executive function.

Focusing further on the older population, according to the report [41] by Hillman, Kramer et al, we found that those with higher physical activity levels were better in overall and local cognitive abilities compared with those with lower physical activity levels. On this basis, some studies have further explored the influence of OSE on executive function. Using measures of behavior and neuroelectrophysiology, researchers compared open skills, closed skills, and irregular practice. The results show that open exercise significantly improves executive functioning in the attention cue, processing speed, and other attentional paradigms. This finding provides a scientific basis for the selection of appropriate exercise methods in older adults, highlighting the important role of open exercise in promoting cognitive health in older adults [42].

From the perspective of visuospatial attention and task switching, the open movement showed a significant positive impact on the visual tracking and spatial positioning ability of the elderly group, [43]. Studies have shown that older people who regularly participate in open exercise show higher accuracy

and faster [44] than completing complex graph recognition and spatial memory tasks. Therefore, for older adults, regular participation in open skills exercises would have a more significant positive impact on [45] in visuospatial attention. This finding further strengthens the potential value of open exercise intervention (OSE) in delaying the process of cognitive aging, and suggests that we should focus more attention on individual differences and exercise types in our future exercise intervention design. This kind of targeted open exercise training can not only effectively improve the autonomy of the elderly in daily life, but also enhance their confidence at the psychological level and promote social interaction. Therefore, the inclusion of such sports in the life planning of the elderly has a positive effect on improving their overall health and happiness. On this basis, encouraging families, communities and professional institutions to participate together and create a more diversified and interesting sports environment for the elderly will become an important measure to promote the construction of an elderly-friendly society in the future.

4 Effect of closed exercises on cognitive function in older adults

In the human cognitive function system, memory occupies a pivotal position. Scientific research has confirmed that human aging is accompanied by the physiological aging process of the brain. In this process, the atrophy of the cerebellum gradually increases from adulthood to old age. The rate of atrophy in the hippocampus and cerebellum gradually accelerated with age. Of particular note, hippocampal degeneration triggers memory impairment later in adulthood, which in turn has a significant negative impact on individual cognitive function [46]. Aerobic exercise was shown to effectively enhance the volume of gray matter and white matter in the frontal cortex, increase the size of the hippocampus, improve spatial memory, and significantly enhance the functional [47] of key nodes in the executive control network. Numerous studies have shown that sustained physical activity is closely associated with the maintenance of the frontal and temporal brain regions, which helps to reduce the risk of cognitive impairment in older people.

It has been demonstrated that the hippocampus and higher health level are closely related to better spatial memory performance [48], and that closed exercise (such as jogging, cycling, etc.) can act more on the hippocampus and increase the size of the hippocampus, thus exerting a positive impact on the memory function of the elderly population. These exercises can improve the cardiopulmonary function, promote hippocampal growth, and enhance memory in the elderly. In addition, these sports can also improve the overall health of the elderly and encourage them to be more active in their daily activities, thus improving their quality of life. Therefore, for the elderly, regular aerobic exercise is not only an effective way to maintain physical health, but also an important means to delay brain aging and protect memory function [49].

Among many studies, when discussing the theme of closed exercise, Taijiquan is often selected as the representative item of this kind of exercise, so as to further explore its specific impact on the cognitive function of the elderly. Taijiquan, as a traditional martial arts form derived from China, not only incorporates the functions of fitness, health preservation and self-defense, but also draws attention for its slow pace and focus on breathing [50]. Tai Chi not only enhances the focus of the elderly, but also greatly improves their sense of balance and coordination. By combining physical exercise with mental exercise, Tai Chi effectively slows down the process of neurodegenerative changes. Taijiquan practitioners need to memorize a series of complex and changeable movements, which greatly exercises their memory. Moreover, the practice of Tai Chi involves the coordination and transformation of multiple movements, which not only improves the cognitive flexibility of the brain, but also enables individuals to adapt and respond faster when faced with new situations. The practice process of Tai Chi is usually accompanied by deep breathing and relaxation, which helps to reduce psychological stress and anxiety, promote sleep quality, and reduce stress in [51]. In the field of cognitive function, relevant studies show that Taijiquan has the ability to maintain or improve the functions of multiple cognitive fields, covering attention, executive function and memory, providing a solid basis for the guarantee of the overall cognitive health of the elderly. Therefore, for the elderly population, participating in locked exercise can help alleviate the physiological function decline associated with aging, prevent the occurrence of disease, and promote the maintenance of physical function. At the same time, it can be inferred that there is a complex interaction between the stimulus of environmental change and cognitive function, and in this process, environmental factors play a key role [52].

5 Discussion

In older adults, the ability of key cognitive areas, such as memory and attention, is affected with age, and they tend to decline. However, through the rule of physical exercise, can effectively delay or even partially reverse the decline trend, significantly improve the elderly cognitive ability and mental health, physical exercise and physical activity can effectively improve alzheimer's disease (AD) of the elderly's cognitive ability [53], so as to maintain the vitality of the brain and overall health. Refinement, in sports, open skills practice (open-skill exercise, OSE) and closed skills practice (closed-skill exercise, CSE) for the improvement of cognitive aspects, physical exercise and aerobic exercise itself can bring certain benefits to the elderly body, on the basis of considering which kind of exercise is a better choice for the elderly [54].

5.1 Disease of cognitive dysfunction

In exploring Alzheimer's disease and cognitive disorders, with Alzheimer's disease (AD) as a typical example, scientific research and clinical practice have shown that there is no medical cure for the disease. In view of this, it is particularly critical and urgent to find and implement non-pharmacological

preventive interventions from a non-therapeutic perspective. However, OSE was more effective than CSE in preventing cognitive decline and dementia than CSE. Previously mentioned, BDNF can affect the cognitive function of the elderly, compared with CSE, OSE is thought to stimulate in the brain brain neurotrophic factor (BDNF) release more effective, therefore, by raising the level of BDNF, can promote the health of the brain and the maintenance of cognitive function, for the elderly with an effective defense cognitive degradation biological pathway [55]. Moreover, open-ended skill exercises can better activate multiple brain regions because of their diversity and unpredictability. Multiregional activation enhances neuroplasticity in the brain, enabling greater adaptation and reorganization in the face of new challenges and learning new skills.

5.2 Working memory, inhibitory control, and conversion

In conducting research to explore the effects of different types of exercise on working memory, the researchers found that open skills exercises had more significant positive effects on inhibitory control and cognitive flexibility in children, adolescents and adults. Specifically, open-skill athletes showed significant reduced response times when performing an inhibitory control task, consistent with their lower time-switching costs in task-switching testing. Furthermore, the exercise intervention had positive effects on inhibitory control function in children and adolescents, further supporting the potential value of open skills exercise in improving cognitive flexibility and reducing the cost of task switching [56]. In addition, open skills exercises can effectively improve adults' performance in working memory tasks, improving their accuracy in completing the tasks. For the older population, the positive effect of open skill exercise in improving working memory is equally significant, and this effect is significantly better than the effect of closed skill exercise [57]. However, in practice, the elderly should fully consider their personal interests, physical condition and living habits when choosing the type of exercise, so as to maintain the durability and effect of exercise. Combining the advantages of OSE and CSE, the development of a personalized exercise program will help them to better maintain their cognitive health and improve the quality of life while enjoying the fun of exercise.

6 Future outlook

Although aging is an inevitable natural physiological change in human beings, we may not have a way to prevent aging, but we can have corresponding strategies to inhibit or reduce the impact of aging on cognitive function, such as through certain exercise. The summary of the study clearly indicates that it is extremely important to participate in a variety of physical activities for the elderly. Comprehensive analysis shows that if the goal is through physical exercise positive effect on cognitive function, open sports activity seems more suitable as the first choice, on the basis of considering individual characteristics and sports load, this study prefers to recommend the elderly to participate in the holding of open sports activities, such as table tennis, badminton, tennis, etc. Several studies have shown that

different sports, including table tennis, have significant effects in improving brain activity and physical coordination among the elderly. For example, table tennis can not only significantly improve the cognitive level of older people, but also enhance their muscle strength and flexibility. Such as table tennis [58], this is a requirement participants must be highly focused, and with faster response decisions, at the same time need to have the corresponding physical foundation to support the related action of open movement, it can not only exercise reaction speed and coordination, also can enhance social interaction in a relaxed and pleasant atmosphere. Insist on doing table tennis 2-3 times a week, 30~60 minutes each time, can effectively delay the decline of cognitive function, improve the quality of life [59]. In the UK, there is an Alzheimer's disease treatment Foundation to support the treatment of AD relief, which shows that table tennis has a positive significance for intervening in cognitive decline. In addition, table tennis is highly popular in the world and has easy access to facilities, making this sport an ideal exercise option for the elderly [60]. On this basis, if combining professional guidance and social activities, it will be more helpful to improve the physical and mental health of the elderly and enrich their later life.

7 Conclusion

The purpose of this study is to investigate the effects of open exercise and locked exercise on the cognitive function of the elderly. Through a series of data collection and analysis, we can deeply explore the role of open exercise in improving the cognitive field of the elderly. In terms of executive functions, including planning, organization, decision-making, and flexible thinking transformation, older people who participate in open sports show better performance. For example, when solving some practical problems in life, the steps can be planned more systematically. The reason why open exercise can have these positive effects on the cognitive function in the elderly may be the result of the joint action of many factors. From a physiological point of view, accelerated blood circulation during exercise gives the brain a more adequate supply of oxygen and nutrients, which helps maintain the normal metabolism and function of neurons and reduces the risk of brain atrophy and neurodegenerative changes due to age. At the same time, exercise can also stimulate the brain secretion of neurotransmitters and trophic factors such as brain-derived neurotrophic factor (BDNF), which play a key role in promoting neuronal growth, repair and synaptic plasticity, laying a physiological foundation for the improvement of cognitive function. Although this research has made valuable achievements, but it is undeniable that there are some limitations, looking to the future research direction, on the one hand, need to further expand the sample size, into more regional, different lifestyles and the elderly with various chronic diseases, to more comprehensive and accurately explore the influence of open movement on the cognitive function of the elderly. On the other hand, more advanced technologies, such as functional magnetic resonance imaging (fMRI), should be used to deeply observe the structural and functional changes of the brain before and

after open movement, and the internal mechanism should be revealed from the neuroimaging level. At the same time, can try to build a more personalized, refined open exercise intervention scheme, on the basis of individual differences in the elderly (such as physical function, initial cognitive level, etc.) make suitable movement type, intensity and duration, to maximize its positive role of cognitive function, to promote the elderly healthy aging provide more targeted and practical advice. In conclusion, open exercise has a positive and significant effect on the cognitive function of the elderly, and reasonable exercise intervention is expected to be an effective means to improve the cognitive level and quality of life of the elderly through reasonable exercise. And in the future, more in-depth research is needed to improve and expand the cognition in this field, so as to better serve the physical and mental health needs of the elderly population.

Disclosure

Author Statement

This article was designed and written by Yuping Zou , responsible for generating the research concept of the entire article, collecting data, and writing the initial draft as well as reviewing and revising. It is hereby declared that this manuscript is original and has not been published before, nor is it currently under consideration for publication elsewhere.All authors have read and agreed with the published version of the manuscript.

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