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To what extent does long-term participation in open-skill sports influence white matter development in the brain compared to closed-skill sports

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Abstract. This study examines the long-term influence of open and closed-skill sport on the development of white matter. The work explores the following academic perspectives: neuroscience, sports science, and psychology. It reports on how neuroplasticity and white matter integrity influence attention shifting and adaptation to unpredictable environments. It also examines whether open-skill sports can delay ageing through their effect on white matter. While the current literature supports the notion that acute exercise can influence white matter, I argue that it is chronic exercise that will have the most profound and persistent impact on the body, because short-term interventions are often limited in terms of depth and their effects are typically transient. In addition, this paper also identifies problems that exist in current research and proposes potential improvements, such as enriching the study types and expanding the measurement data. Practical suggestions for future application are provided too. The paper’s key finding is that long-term participation in open-skill sports is indeed associated with enhancements in cognitive function and physiological performance. Further, it may offer significant benefits in mitigating the effects of aging, if this issue can be explored through more in-depth research. Overall, open-skill sports are shown to have great potential to improve brain health and cognitive abilities.

Keywords: open skill sports, closed skill sports, white matter integrity, neuroplasticity

1. Introduction

It is already known exercise is good for the brain [1], but does the type of sport we engage in make a difference? Specifically, how does long-term participation in open-skill sports like badminton, which require continuous adaptation and quick decision-making, affect the microstructure of the brain's white matter? I have a deep personal resonance with this topic. As an experienced badminton player and enthusiast, such open-skill sports have truly brought profound benefits to my life, especially in terms of feeling more alert, reacting faster, and even becoming happier after exercising. This is therefore an important topic that I hope can help develop our understanding and help more people.

Sports can be categorised into 'open-skill' and 'closed-skill' types [2]. Open-skill sports (e.g., badminton, tennis, football) are characterised by dynamic, unpredictable environments where players must continuously

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adapt their actions in response to opponents and changing circumstances. In contrast, closed-skill sports (e.g., running, swimming) involve stable, self-paced environments with repetitive movement patterns. Regarding more about the current research, the majority of existing literature has focused on the effects of general aerobic exercise on grey matter volume or has treated "exercise" as a monolithic entity. This has created a significant gap in our understanding. The unique, high cognitive-motor demands of open-skill sports suggest they may be particularly potent stimulators of neuroplasticity [3] in the white matter tracts responsible for complex coordination and rapid information processing. Yet, the specific mechanisms and outcomes remain underexplored compared to other forms of physical activity [4].

In recent years, research on the relationship between exercise and neurobiology had not been deep developed. Regarding the content of my thesis topic, most people focus primarily on the theoretical findings, while only a few consider how we can leverage these results to improve human behavior and health. For this key element, I believe the topic of my paper - the impact of various types of exercise on white matter in the brain, could provide such ideas and help to this area of learning. White matter, comprises millions of myelinated axons. Increasing the speed and efficiency of electrical communication [5] between distant neural regions. The integrity of this white matter network is fundamental to optimal cognitive performance, including processing speed [6], promote several functions, and took part in learning.

Therefore, this paper aims to synthesize current academic research to investigate this potential differential impact [7]. The scope of this dissertation is inherently interdisciplinary, encompassing neurobiology, sports science, and psychology. The main attention will be placed on biological factors, in particular neurobiology and mechanisms of neuroplasticity. This is supplemented by elements of applied biology, examining how biological principles manifest in trained athletes. Furthermore, the science of sport and exercise will be extensively addressed, as the subject is inextricably linked to the biomechanical and physiological.

2. Research review

The brain - the primary center for human thought and control - it is composed from many structures, each with its own function. Within these, one structure connects all the brain's organs and tissues: the white matter, which known as a bridge for information communication.

2.1. Foundational concepts in neuroscience

The Collins Dictionary definition of White Matter is: 'the whitish tissue of the brain and spinal cord, consisting mainly of myelinated nervefibres'.

According to this definition, white matter is the primary tissue responsible for transmitting neural signals between brain regions, composed by myelinated axons. As the name suggests, it is called 'white matter' because of its whitish appearance (see Figure 1).

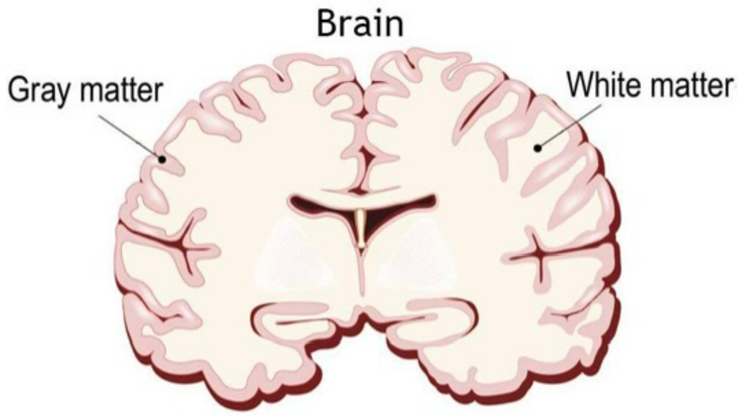

Figure 1. Brain white matter appearance

Its function is mainly involved in the brain, where white matter is made up of myelinated nerve fibres that are responsible for transmitting signals frequently, connecting different brain regions, and supporting the development of cognitive, motor, and sensory functions. If it has been destructed, it may lead to impaired information transmission, affecting memory, language, and executive function. To simply conclude, it serves as the 'information highway' of the nervous system, connecting and enhancing the integration and efficiency of brain functions.

To understand how white matter functions, one must recognize its fundamental building blocks - neurons. Neurons are the primary structure of the nervous system, responsible for receiving and transmitting information through electrical signals. They consist of three main components:Soma, dendrite and axon, which shown on Figure 2 below.

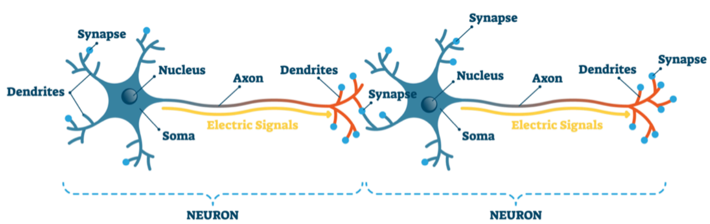

Figure 2. Neuron structure diagram

From Figure 2, we can see that a neuron has a branched structure called dendrites, whose main function is to receive signals from other neurons, and the signals were released by the synapses of the previous neuron. After that, all the information received by the dendrites were converted into the soma. The soma is remarkable, if the accumulated information reaches a certain maximum value, then the neuron will be activated. Following this, the neuron generates a powerful electrical signal, known as an "action potential," at the initial segment of the axon. The axon is then utilized to propagate this electrical signal more efficiently to its terminal. Finally, when the electrical signal reaches the presynaptic terminal, it triggers neurotransmitters. These neurotransmitters cross a gap and bind to the receptor (dendrites) of the next neuron, then a complete cycle of neural transmission formed.

2.2. Link neuroplasticity to white matter integrity and sport

The brain is not a static organ. Neuroplasticity refers to the nervous system's ability to change its activity in response to intrinsic or extrinsic stimuli by reorganizing its structure, functions, or connections after injuries (National Library of Medicine). This is the fundamental biological mechanism through which physical activity, like sports, can influence white matter structure [8].

Neuroplasticity is closely linked to the brain. It can be divided into two types: experience-dependent and structural. The difference between them lies in the main function they convert, the experience-dependent former relocates synapses from damaged brain regions into active areas, while the latter alters neural processing based on memories or experienced events. Neuroplasticity operates at both micro and macro levels. Macro level is closely related to the micro level. When micro-level changes accumulate to a certain ex-tent, they trigger changes in macroscopic structure. In the cerebral cortex, which is responsible for higher-order functions, neural mapping is not fixed. Although it was once believed that no new neurons were generated in adulthood, research has shown that certain brain regions can generate new neurons throughout life, by participating in learning and memory pro-cesses rapidly.

A core outcome of this macro-level remodeling is enhanced white matter integrity. White matter integrity is a key brain imaging metric. It assesses the health of myelin sheaths and the structural organization of axons. Proper myelination and well-aligned fibers work together to ensure efficient, synchronized neural transmission with minimal signal delay.

Open skill sports is characterised by the body movements which are influenced by the dynamic and external pace environment. This type refers to physical activities performed in an unpredictable and dynamically changing environment, such as those requiring constant adaptation to the movements of opponents and teammates. Specific examples include badminton, football, and basketball. Open-skill sports require high cognitive demands on participants, particularly in the areas of attention, sensory integration, and rapid decision-making. Athletes must consistently anticipate the trajectory of the ball while depending on extensive muscle memory.

Regarding to the demand for highly efficient neural transmission, the brain produces more myelin to wrap around frequently activated axons, making neural pathways thicker and more efficient. In addition, the corticospinal tract, where the pathway from the motor cortex of the brain to the spinal cord is also affected. The degree of myelination in this tract directly influences the speed and accuracy of motor command delivery.

Therefore, from the perspective of neuroplasticity, engaging in cognitively and physically demanding sports imposes intense, specific loads on relevant neural networks. To meet this demand more efficiently, the brain undergoes neuroplastic adaptations. A key form of this long-term adaptation is enhanced white matter integrity. To support the rapid, synchronized neural discharges required for complex tasks, the brain may increase myelin production around frequently used axons and optimize the arrangement of fiber bundles. This process is supported by neuroimaging studies, directly improving the speed and fidelity of signal transmission between brain regions [5]. Higher white matter integrity have relatively large benefit for the brain. The most immediate advantage shows in the enhancement of information processing speed, this remains well-established and proofed. Furthermore, it strengthens cognitive function, since white matter connects brain regions responsible for different functions, its integrity directly supports the efficiency of neural networks, providing fundamental structure for both motor and cognitive learning.

At the same time, white matter integrity also offers resistance against aging. High white matter integrity enhances the resilience of neural networks, which is mainly reflected in the brain's ability to compensate through alternative pathways when normal age-related connectivity decline occurs, thereby delaying functional deterioration. Research shows that individuals who regularly engage in complex motor activities exhibit slower age-related white matter decline.

2.3. Comparison between open and close skill sports in various dimensions

Closed skills are rigid, pre-choreographed routines in stable environments. Open skills demand fluid, adaptive responses to unpredictable, dynamic situations. As show in Table 1, this framework shapes how we train, rehab, and learn movement.

Table 1. Conclusion of differences between open and close skill sports

Dimension	Open skill sports	Closed skill sports
Attention allocation	External Attention: Highly focused on environmental cues. Broader attentional focus.	Internal Attention: More focused on their own kinesthetic feel, technical details, and rhythm. Narrower, more concentrated focus.
Decision-making mode	Adaptive decision-Making: Requires rapid processing of uncertain information to make flexible, non-habitual reactions. Relies on working memory and cognitive flexibility.	Pre-programmed Decision-Making: Executes well-rehearsed, automated movement patterns. The decision process is more automatic.
Core cognitive ability	Executive Functions are highly demanded, especially: - Inhibitory Control: Suppressing irrelevant distractions or habitual responses. - Task Switching: Flexibly switching between	Motor Control and Sensorimotor Integration are highly demanded. Pursues extreme movement consistency and precision.
Brain activity and structure	The Prefrontal Cortex is likely more active or developed. The PFC is the centre for higher-order executive functions, complex decision-making, and cognitive control.	The Cerebellum and Primary Motor Cortex are likely more developed. These areas are closely related to executing skilful movements, timing, and automation. Stronger concentration, consistency, and ability to perform repetitively.

The most important distinction is in the primary neural systems that are engaged. Closed-skill motor activities centre around internal attention, movement automation, and consistency. These kinds of activity primarily challenges and optimises the cerebellum and primary sensorimotor circuits. Therefore, the expected white matter changes are primarily evident in tracts such as the corticospinal tract and the cerebellar peduncles that support motor execution, proprioceptive feedback, and temporal aspects of movement. The plasticity here involves achieving efficiency and accuracy within a stable framework.

In contrast, open-skill activities train the frontotemporal (executive) network more holistically. Their sustained demands for external vigilance, rapid stimulus evaluation, inhibitory control, and adaptive decision-making place a persistently high load on the prefrontal cortex and its connections to sensory and motor regions. Hence, the resulting high demand for stress management creates a powerful driving force for plasticity in associative white matter tracts like the superior longitudinal fasciculus, which mediates communication between frontal, parietal, and temporal lobes at great speed. This is an ability that is critical for cognitive control and situational awareness.

Beyond this, closed-skill activities depend on high-precision and stable communication within tightly coupled motor circuits. Open-skill movements are underpinned by time-sensitive, integrated, and flexible interaction among distant brain networks. Such a distinction is also important, as a greater complexity of networks enhances the stimulation for white matter growth. Since long-range associative fibres are especially important for open-skill tasks, it may be possible that the brain's information processing speed and adaptability can be enhanced by increasing the myelin integrity of long-range associative fibres. This may contribute to explaining the superior cognitive flexibility and executive function often reported among athletes in open-skill sports, consistent with existing literature.

Therefore, long-term participation in open-skill sports is likely to have a broader and more profound impact on white matter development. Although the integrity of both types of motor-related pathways are modulated by playing sports, open-skill sports specifically and strongly facilitate the formation of the "superstructural" white matter networks that are responsible for higher-order cognition and adaptive behaviour. This is not to discount the value of closed-skill sports, but it highlights the more pronounced bias of the latter toward specialized neuromuscular effects, whereas open-skill sports deliver overall brain network optimization.

2.4. Empirical evidence from sport and exercise neuroscience

In an effort to confirm the effect of white matter and its integrity on the human body, I reviewed several research findings from studies that involve different age groups. After comparing and synthesizing these results, I was able to form an evidence-based conclusion which is as follows:

1. The Influence of Aerobic Fitness on White Matter Integrity and Inhibitory Control in Early Adulthood: A 9-Week Exercise Intervention [9].

In the study by Zhu et al .[9], the research question was whether a 9-week aerobic exercise program could enhance white matter structure. Healthy young university students were divided into an exercise group (9 weeks of supervised aerobic training) and a control group (no exercise program). The exercise group exhibited significantly increased white matter integrity in the splenium of the corpus callosum compared to the control group. This change was positively correlated with improved inhibitory control, indicating that short-term aerobic exercise can induce neuroplastic changes linked to cognitive enhancement.

2. Comparative effects of open-skill and closed-skill sports on executive function in university students: a 16-week quasi-experimental study.

This investigation examined the impact of closed-skill (golf) and open-skill (soccer) exercises on executive function. In a 16-week intervention, 63 university students were randomly assigned to golf, soccer, or sedentary control groups. The results demonstrated that closed-skill exercises can also lead to specific improvements in executive functions such as inhibitory control as effectively as dynamic open-skill sports.

3. White matter integrity as a marker for cognitive plasticity in aging.

This research tracked 45 young men to study whether regular exercise actually changes the brain's wiring. Using brain scans taken before and after the program, the researchers assessed changes in the white matter, i.e., the brain's communication network. They found that after six months of exercise – no matter whether cardiovascular exercise or strength training - the active group showed clear improvements in brain structure, specifically:

1) Nerve fibres became more intact and efficient, especially in areas linked to complex thinking, like the frontal lobe.

2) Key indicators of white matter health improved across multiple brain regions.

3. Discussion

3.1. Why open-skill sports may be superior for white matter plasticity

Based on the aforementioned analysis of neuroplasticity mechanisms and the differences between open-ended and closed-ended skill movements, and taking into account the results of three key experimental studies, we can draw more reliable conclusions about the impact of participating in open-ended skill movements over the long term on white matter development.

Firstly, experimental evidence suggests that physical activity can directly and effectively induce positive plastic changes in white matter. Both the 9-week aerobic intervention study by Zhu et al. (which showed a correlation between increased white matter integrity in the corpus callosum and improved inhibitory control) and the 6-month exercise programme (which demonstrated widespread enhancement of white matter health indicators across multiple brain regions) confirm the efficacy of exercise as a driver of neuroplasticity [9]. These findings provide empirical support for the hypothesis that 'exercise influences white matter'.

However, answering the question "Which type of exercise has a greater impact?" requires an analysis of exercise specificity to be introduced. A second comparative study offers crucial insights: a 16-week intervention demonstrated that both open-skill (e.g. football) and closed-skill (e.g. golf) activities improved executive function in college students. While this finding may initially seem to reduce the distinctiveness of open-skill activities, it actually suggests further research directions: the two types of exercise may produce similar behavioural outcomes through different neural mechanisms. According to our theoretical framework, we hypothesise the following: Closed-skill sports may enhance focus and precision control by optimising the efficiency and consistency of sensorimotor pathways. In contrast, open-skill sports may more effectively strengthen cross-regional integration networks centred on the frontal cortex, thereby improving cognitive flexibility and complex decision-making abilities. We anticipate that these differing mechanisms will manifest in distinct target regions for white matter remodelling, such as association and projection fibre tracts.

Therefore, the conclusion regarding the 'extent of influence' cannot be based on a simple linear comparison. From the perspective of behavioural benefits and support for higher-order cognition, long-term participation in open-skill sports is likely to have a more profound impact on white matter development. The advantage of this approach lies in the fact that it simultaneously and intensively drives the coordinated development and optimisation of the two major brain systems responsible for cognitive control and sensorimotor integration through continuous adaptation to a dynamic environment. This kind of "integrative training" for complex brain networks may not only confer immediate advantages in information processing but also, as hinted at by the third study, help build greater structural reserve for the brain. This, in turn, could more effectively counteract age-related white matter decline over the long term and delay cognitive aging.

In summary, the existing evidence supports a tiered perspective: 1) Exercise is generally beneficial for white matter health; 2) Open and closed-skill sports likely enhance cognition through differentiated pathways; 3) Due to the unique and sustained integrative demands that open-skill sports place on advanced cognitive networks, long-term participation holds the promise of exerting a more comprehensive and functionally significant influence on the development and maintenance of white matter.

3.2. Issues on current investigations

Research relevant to my essay topic remains quite limited today, and the existing information of work has only emerged in recent years. I believe this topic could bring significant importance to the area of subject, with numerous aspects worthy of exploration. However, current studies have only scratched the surface, and there is also a notable scarcity of concrete experimental investigations. This is one of the main reasons why I have chosen to analyse this subject for my thesis.

3.2.1. What kinds of improvements could be created on experiments?

In my constant deeply contemplation, I find it more meaningful to change the current research approach than other kinds of information. Overall, I'd like to explore what changes we can make beyond conventional experimental testing methods, such as alter the way we experiment, or refurbish the data that we require to make conclusions.

3.2.2. Types of innovative tests that can be envisaged

Firstly, starting with the imaging aspect, there's a limitation of the current testing approach is that brain imaging Diffusion Tensor Imaging (DTI) is conducted only after a period following exercise, people that have been tested take the DTI scanning about 5 to 12 hours after exercised with sports, but this doesn't really make sense, we should take the DTI and other tests just after the people done sports activities.

To tackle this, there's a practical approach to monitor brain activity in real-time while subjects are actually engaged in open-skill sports. We could use tools like fNIRS to tackle with. The fNIRS, full name is "functional Near- infrared Spectroscopy". This is a very important brain function imaging technology. This technology indirectly deduces some theories by measuring the changes in hemoglobin concentration in the cerebral cortex blood flow: when a certain area of the brain is particularly active, the neurons in this area consume more energy. Therefore, to meet this demand, the blood flow brings more oxygen (inside the hemoglobin), leading to an increase in the concentration of oxygenated hemoglobin in this area. Then, we can use this principle to infer the state of brain activity.

Although fNIRS appears advanced and useful, some of its characteristics actually make this measurement method impractical. The main reasons are really inevitable: First, motion artifacts, including rapid head movements, can cause instantaneous changes in the coupling between the light source and the detector. Due to this sensitivity, fNIRS cannot effectively measure dynamic objects. Second, also equally important to the first reason, if we need to measure instantaneous changes in the brain during open-ended movements, it would require placing the detector directly adjacent to the area. Unfortunately, the penetration depth of fNIRS light is only 1.5–3.0 centimeters, making real-time measurement during movement impossible. Additionally, there are various other limitations that indeed affect the usability of fNIRS. Therefore, I believe the best solution is to let the tester quickly move to the fNIRS detector immediately after completing the open-ended movement, so the brain state has not yet readjusted, the state is still remaining, then we can achieve the same effect.

Secondly, another idea is using VR technology. Imagine setting up a scenario where participants have to handle multiple motor tasks at once, things like solving calculations while avoiding obstacles and doing memory exercises. What's interesting about this design is that it could really test whether open-skill athletes perform better under multitasking pressure. If they do, it would strongly suggest these athletes have more efficient white matter connectivity and greater cognitive flexibility.

Thirdly, another rather innovative technique is that of combining Diffusion Tensor Imaging (DTI) with Magnetic Resonance Spectroscopy (MRS). This rationale resembles the VR approach and aims to capture modifications in brain activity and structure within one experimental design. DTI is used to characterize the microstructural integrity and connectivity of white matter, while MRS is used to characterize the biochemical profile of specific brain regions. For instance, we can examine metabolites such as choline, cortisol and others, within the very same pathways whose structural integrity is measured with DTI. This kind of integrated analysis not only tells us whether the brain is altered in the period following exercise, but also provides clues about the reasons, such as whether the changes are related to metabolic dysfunction, neuroinflammation, or stress-related plasticity.

Something else we might do in this regard is to record participants' eye movements and how quickly they react to specific objects in these simulated environments. That form of test would be especially effective for revealing whether open-skill athletes truly have an edge in strategic planning and reaction time.

3.2.3. Other data types that can be supplemented

Given the present research status, people tend to focus only on measuring data such as heart rate, maximum oxygen uptake, body fat percentage, and weight, without considering the addition of different types of data. Through my own reflection and analysis, I believe improvements can be made in this area. These categories of data are different from other types, and they tend to be more personalized. However, despite being personalized, these data still maintain relevance to our topic. I will explain this in detail next.

First and foremost, one aspect that is highly recognised would be to conduct a blood test to detect biomarkers related to neuroplasticity and inflammation. A specific case in point would be the tracking of insulin-like growth factor or certain types of disease factors. These biomarkers can be said to represent the real-time effects of open-skill sports on neuroprotection and inflammation modulation.

Another valuable source of data may be questionnaires that focus on evaluating psychological and behavioural changes. For these questionnaires, established standardised scales of assessment can be applied for the evaluation - so there's no need to construct questions for the study. Pre-made tests can be obtained from the appropriate web sites. Yet another very beneficial evaluation is the Gallup assessment, which analyses the strengths and weaknesses of the person taking the test. This test ranks more than 30 evaluative elements from the most significant to the least significant, offering clear insights into one's advantages and areas that need improvement. Nonetheless, this test is not suitable for frequent use; conducting it once a year is the optimal timeframe, although the interval may admittedly feel somewhat long.

3.3. Sociological observations: preference vs. optimal benefit

It must be acknowledged that playing open-skill sports such as badminton does provide unique sensations both psychologically and physiologically. It's more than just tired, it's a part of a bigger, whole-body sensation. Physiologically, the immediate exhilaration and sense of exhaustion during sport are definitely satisfying. That kind of muscle soreness and fatigue, known as "delayed onset muscle soreness," bring a sense of accomplishment, as if telling me, "I pushed myself today." In the long term, such exercise significantly enhances physical stamina and improves coordination and reflexes.

From a psychological standpoint, the sensations that are brought by playing badminton tend to be even more profound. I often experience instant emotional release and stress relief—actions like smashing and saving the shuttlecock provide a vent for pent-up emotions. Moreover, the long-term psychological benefits include increased self-confidence and improved mood. These sensations and improvements are not only evident in myself but also in others who exercise similar to me.

Why do many "high-profile figures" prefer closed-skill sports over open-skill ones? For this group of people, they possess extremely high IQs and abundant experience, and are highly renowned in various industries. However, people are pondering one thing - since open sports bring so many benefits to individuals, and these benefits and growth are precisely what these successful entrepreneurs need, why do they tend to prefer closed sports? People may have concerns and cognitive blind spot on this event.

One might assume—and my own experiences also align here—that since open-skill sports significantly enhance mental agility and concentration, therefore top entrepreneurs and leaders would naturally participate in them frequently. Yet, upon reflection, that doesn't seem to be the case. In fact, many of these influential figures appear to prefer closed-skill activities such as golf, swimming, yoga, or fitness training. So, why is that?

If we think about it logically, this offers an important point to consider. It really comes down to physical risk. For open-skills sports, people are running, jumping, making sudden stops and sharp turns, and there's usually physical contact involved. All that action naturally leads to a higher chance of getting hurt: sprained ankles, torn anterior cruciate ligaments in the knees, muscle pulls. Now, imagine a top executive or a key professional engaging in that - one serious injury could mean missing critical meetings, derailing projects, and ultimately costing a fortune to fix the disruption.

This is where closed-skill sports really shine. Activities such as swimming, golf, or cycling are simply much more controllable. They're easier on the joints, and you don't have to concern yourself with sudden collisions like you do in basketball or soccer. And for the professionals who rely on their body and mind to be consistently trustworthy, that lower risk profile is a huge part of the appeal - it directly supports their need for sustainability.

Secondly, if we again carefully consider: those who have risen to the top clearly already have strong cognitive skills. Constantly pushing in open-skill sports would just drain them further. What they really need is to conserve energy and let their minds and bodies recover. I mean, after a long day of intense mental work, if you go play a high-intensity game of basketball or soccer, you're likely to feel exhausted the next day, or even get sick. That's why they go for closed-skill sports—it's almost a form of active rest that allows their brains to relax and recharge.

Thirdly, the social dimension cannot be ignored. For many leaders and influential figures, closed-skill sports aren't chosen just for physical benefits. Remember those kinds of movie scenes? A private game of golf or a swim is not just a game. It's a perfect situation for confidential discussions. Under the cover of a shared activity, they can build trust and relationships. This function as a private networking space is a major, if unwritten, rule of the game for them.

3.4. Some opinions that remain problematic

Nowadays, the relative studies and investigations still remain problematic, so these points should be point out and give suitable improvements.

The second study concluded in my literature review state that "enhance specific executive functions like inhibitory control as effectively as dynamic open-skill sports." However, my point of view was different from that. I maintain that open-skill sports hold more potential on improving cognitive abilities and white matter integrity rather than closed-skill sports.

While this article does highlight the notable performance of closed-skill sports in certain domains, but that doesn't really make sense. The benefits of open-skill sports may performances in a more advanced stages of cognition. In my view, these findings do not directly refute the advantages of open-skill sports. Instead, they inspire us to recognize that future research must adopt more innovative approaches in order to fully uncover their cognitive benefits.

The second point addresses the debate over whether short-term exercise is sufficient to induce significant white matter changes. My position is inevitably that long-term open-skill sports are necessary to bring about substantial improvements in white matter integrity and anti-aging benefits. However, the first and third studies cited in my literature review suggest the opposite view - they argue that experimental periods of just nine weeks and six months, respectively, can already lead to significant changes.

Yet there is a considerable issue here. Many participants in these experiments had rarely engaged in physical activity before undergoing the interventions, so the notable changes in their brains may largely be attributed to a sudden jump in exercise frequency. Consider this, if someone never studied mathematics and always scored single digits in exams, but then underwent intensive daily math training for several months, that person would inevitably improve by dozens of points in the next exam. The same logic applies to this argument too.

Therefore, the optimization brought about by years of long-term open-skill sports experience is likely more profound and structurally stable than that achieved over just a few months. Thus, I believe that short-term studies demonstrate the "potential" for change, whereas long-term tracking is necessary to reveal the "ultimate value" of open-skill sports in constructing a more resilient and efficient brain network.

4. Conclusion

As illustrated in the experiments, long-term participation in open-skill sports (such as badminton and football) has a significantly better effect on improving white matter integrity than closed-skill sports, especially in terms of cognitive flexibility, decision-making speed, and anti-aging. The conclusion of the points is based on sources such as neuroplasticity, white matter integrity, and the dual requirements of cognition and movement, thus learned, and this conclusion was also reached by combining and citing many related studies.

Regarding my research and findings, the conclusion also suggests that: open-skill sports can significantly promote and enhance white matter integrity, especially in areas such as the corpus callosum and the prefrontal-spinal tract. These types of sports enhance executive abilities such as inhibitory control, attention allocation, and task switching. Similarly, long-term participation can also delay white matter aging, so means delaying physiological aging. As for closed-skill sports, they are indeed beneficial, but their improvements in cognitive flexibility and adaptability are limited and cannot compare to open-skill sports.

Regarding the contribution of this research: neuroscience, sports science, and psychology, this is for discussion and research. I have not only proposed the major effects and mechanisms of open-skill sports on white matter development, I have also suggested some improvable experimental data types, research methods, and similar innovative ideas, such as fNIRS. However, to be honest, the current existing real experimental samples in my research area are extremely limited, and the experimental cycles are relatively short. Therefore, further deeply research requires more information. For example, we are currently lack of large-scale population comparisons across different ages, genders, and exercise intensities. Similarly, most existing studies are short-term and lack long-term tracking information and data. This is also an area where I believe future researchers can focus on improvements, after all, the reason for that is due to the topic of this research have potential to holds significant value for humans.

Overall, we must admit that current research has such drawbacks, so I believe future research should prioritize multifaceted and multi-modular studies. To say, on the basis of existing research, more attention should be paid to different age groups, different experimental periods, and the integration of multiple brain imaging technologies to monitor data. This is the most suitable way that can we can further verify these theoretical findings and translate them into real-world applications.

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