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*OBM Neurobiology*

Original Research

# The Impact of Physical Activity on Brain Neuroplasticity, Cognitive Functions and Motor Skills

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**Academic Editor:** Ping K. Yip

**Special Issue**: Neuroprotection, Neuroregeneration and Neuroplasticity

*OBM Neurobiology*
2024, volume 8, issue 2
doi:10.21926/obm.neurobiol.2402219

**Received:** December 20, 2023
**Accepted:** April 19, 2024
**Published:** April 25, 2024

**Abstract**

The research aims to study the mechanisms and factors contributing to brain neuroplasticity. To achieve this goal, the following methods were used: analysis and synthesis, hermeneutic method, psychological testing, and comparative and generalization methods. The research results revealed the nature of the concept of brain neuroplasticity and types of neuroplasticity, analyzed the process of redistribution of brain functions, determined the role of compensatory plasticity, revealed methods of studying brain neuroplasticity, investigated the influence of brain processes on the course of learning, memory development, awareness, concentration, speech; identified factors that can affect brain neuroplasticity revealed the role of genetic factors, analyzed stimulation and rehabilitation methods to promote neuroplasticity. The findings may aid in developing novel rehabilitation techniques, specifically for stroke patients, by utilizing the brain's compensatory abilities through physical activity, pharmacological interventions, and stimulation techniques. The practical significance of the research is determined by the current disclosure of the features of brain neuroplasticity to understand its ability to reorganize the sensory and perceptual systems.

**Keywords**
Cognitive processes; executive functions; neuroimaging technique; electroencephalography; stimulation; compensation

## 1. Introduction

A person takes care of their body and visual and somatic health using various physical activities and kinesics to ensure full functioning and well-being. Still, it should be noted that the brain is the most important muscle that needs to be trained daily to prevent pathological disorders, avoid neurological diseases, and stimulate additional development of one's capabilities. The main criterion for practical brain training is the ability to go beyond the usual actions, avoid monotony, and devote attention and time to mastering additional skills. New synaptic connections formed through neuroplasticity ensure positive psychological health and cognitive flexibility, which can be developed through non-standard solutions. According to the World Health Organization [1], the brain and nervous system are the command centers of the human body, controlling conscious and unconscious processes. According to statistics, destructive social conditions and the lack of adequate financial support affect the mental capacity of society. One in three people suffers from a neurological disorder, which is the leading cause of developmental delays, disability, and mortality. Statistics show that 43% of children under 5 years of age have growth retardation and loss of mental potential, which is the result of economic hardship and lack of access to quality services.

D.S. Suhan et al. [2] found that neuroplasticity plays a vital role in the recovery and prevention of neurological diseases, namely stroke, epilepsy, Alzheimer's disease, migraine, headaches, etc. According to the researchers, brain neuroplasticity is a natural response of the nervous system to environmental changes, contributing to the functional restructuring of nerve cells that form new and stable neural contacts. Researchers have found that neuroplasticity can be improved by artificially injecting neurotrophins (a regulatory protein), which can help restore sensorimotor function in stroke patients. D. Zakharov and V.O. Mykhailov [3] argued that tissue damage to the brain acts as a trigger for the development of neuroplasticity, which is actively involved in rehabilitation after organic injuries or stroke. Still, the final positive result is additionally influenced by regular physical activity and pharmacological combinations specially selected by a doctor.

V. Grechukha and D. Otych [4] stated that changing the habitual way of life and learning, the desire for constant self-development can change brain functionality because when learning unusual information and training creative skills, the brain forms new neural connections that can be strengthened during repetition and memorization. Researchers have argued that the brain's neuroplasticity allows the nervous system to change and adapt to unusual conditions, regardless of a person's age, providing sensory substitution. N. Doidge [5] noted in his book on brain recovery and abilities that effective psychotherapy can act as a stimulant of brain neuroplasticity, which is based on a variety of methods and approaches that can change thinking, behavior, and perception of the environment, and that such changes occur at the level of neural formations. According to the psychiatrist, psychotherapy can modify the brain's neural networks and affect behavioral patterns, habits, routines, and anxiety. A. Kolomiets et al. [6] revealed in their study that forming new neural connections takes time, which can take about twenty days of specific training and practice. The researchers emphasized that active learning of musical instruments and attending language courses, sports, or creative clubs can have a qualitative impact on the brain's cognitive functions, contribute to its receptivity to new information, and facilitate its effective assimilation, especially in preschool and school age.

The study aims to provide a detailed investigation of brain neuroplasticity and its ability to adapt in response to endogenous and exogenous stimuli and identify ways to develop neuroplasticity for practical applications in medicine, psychotherapy, and psychiatry. This research aims to comprehensively investigate the neuroplasticity of the brain and delineate its capacity to facilitate adaptive and compensatory functions, including sensory and perceptual substitution. Factors such as physical activity, skill acquisition, psychotherapeutic interventions such as mindfulness and exposure therapy, and pharmacological treatments will be examined for their effects on promoting and stimulating brain neuroplasticity. The study seeks to analyze the potential applications of neuroplasticity in medical contexts, particularly in rehabilitation following stroke or brain injuries. The research will address the role of neuroplasticity in improving cognitive functions such as memory, attention, perception, and mental flexibility, with implications for education and skills development. Empirical studies and experiments, including visual-motor coordination tests and motor sequence assessments, will be conducted to explore the relationship between physical activity, cognitive processes, and brain neuroplasticity. The study will compare and evaluate different methods and techniques, such as neuroimaging, brain stimulation, and psychological tests, to study and manipulate brain neuroplasticity, thereby contributing to a deeper understanding of this phenomenon and its potential applications.

## 2. Materials and Methods

The analysis method was used to develop the theoretical foundations for the nature of brain neuroplasticity, reveal its ability to redistribute functions and compensatory properties and analyze the impact of brain processes on learning, memory, and the second signaling system. This method was used to identify factors that can affect the brain's neuroplasticity and reveal possible genetic factors. The synthesis method summarized and integrated the information obtained, providing a complete picture of brain neuroplasticity for further developing new approaches in medicine, education, rehabilitation, and psychotherapy. The hermeneutic method was used to interpret medical terminology, namely brain neuroplasticity, neurogenesis, brain maps, reveal types of neuroplasticity, and explain technical brain stimulation methods and rehabilitation principles.

The comparative method was used to compare past experiments and approaches with our practical research, analyze preventive and rehabilitation techniques to promote neuroplasticity, determine the role of psychotherapeutic approaches in promoting the development and stimulation of neuroplasticity, and explore the main graphical methods of studying brain neuroplasticity. This method was used to establish the relationship between specific stimuli and changes in brain neuroplasticity and to compare empirical indicators of cognitive functions that can be affected by physical activity. The generalization method was used to combine the processed data into a single structure for understanding the nature and capabilities of the brain and establishing the main regularities and principles that reflect the process and functioning of neuroplasticity in a broad scientific context.

The study of visual-motor coordination was conducted to analyze the ability to memorize quickly coordinated movements that require interaction between motor activity and the visual system to identify the impact of regular physical activity on cognitive processes, as these features, according to scientists, can emphasize the effective functioning of the brain, indicate its neuroplasticity and adaptive flexibility. Four teams (11 players per team) took part in the study, which totaled 44 subjects, and a control group of people who were not involved in sports and led a normal lifestyle consisting of classical work or study totaled 44 people.

The athlete sample consisted of field hockey players aged 18-25 years who were actively training and competing at the time of the study. Participants were recruited from local field hockey clubs and university teams. Screening was conducted to exclude individuals with severe physical injuries, neurological disorders, or substance abuse issues that could confound the results. The control group of non-athletes was selected to match the age range of 18-25 years. Participants were screened to exclude those actively involved in competitive sports or highly physical occupations. The effort was made to include a diversity of professions and activities in the control group. All participants provided written informed consent. To implement this method, the "Hand-eye coordination test" was used, consisting of a task depicted on the form in numbered circles from 1 to 25 [7]. The task of each respondent was to combine these numbers according to their ascending order as quickly as possible (ideal performance was 10-50 seconds) without taking the pencil off the paper. During the process, the state of each subject was additionally observed, considering reactions, emotional components, vegetative characteristics (redness of the face, increased breathing, shaking of the hand), speech (whispering, silence, comments, loud speaking), the nature of fatigue, manifested in the speed of performance and the shape of the lines.

The motor sequence test "Assessment of Motor and Process Skills" was also used among hockey players to test the scientific claims about the impact of daily training on the effectiveness of cognitive functions [8]. The subjects were presented with movements and gestures to be reproduced after a certain period. This test evaluates the ability to memorize and reproduce motor sequences, the quality of which may depend on daily training practice, which affects not only physiological features but also the development of cognitive functions, the formation of new neural connections, and the ability to remember the necessary information.

## 3. Results

The results of the hand-eye coordination test showed that the hockey players coped with the task much faster, with a performance range of 35 to 46 seconds, which was generally equal to an average coordination index, as the individuals performed the task without any noticeable difficulties, demonstrating accurate and balanced movements. Twelve subjects showed minor discoordination, accompanied by minor problems during the task and partial discrepancy between movements and visual perception. Still, the movements were generally acceptable and controlled, with a performance time of 49-55 seconds. This result could be due to additional organic factors that do not relate to cognitive functions (emotional, physical, or visual fatigue). These respondents felt tense, had intense pressure on the sheet, were partially confused about finding the right numbers, and had slight irritability. There was no pronounced discoordination or general inability to complete the test; the players successfully and quickly completed the task with an average score.

In this case, the results obtained can be explained by the behavior developed during sports. These professional movements allow one to navigate space effectively, focus on the desired figure, remember clear, precise positions to resist opponents and develop motor skills. Some of the respondents compared the task sheet to a playing field, additionally noting that this association allowed them to find the necessary and consistent numbers faster and that there was an automatic adaptation to artificial conditions, the effectiveness of which is probably based on daily experience, which may partially support the explanation of the development of neuroplasticity through constant and intensive training for quality and performance of practical actions (Figure 1).

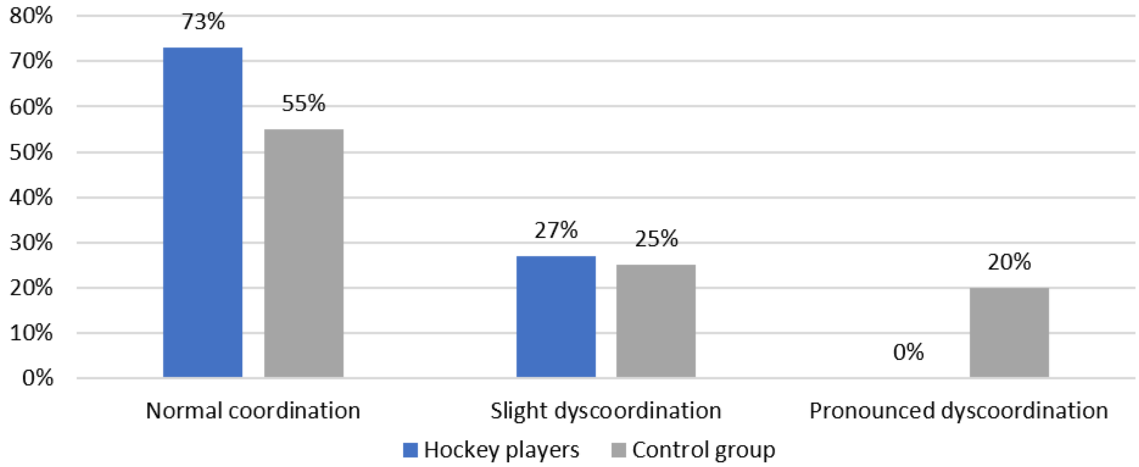


**Figure 1** Indicators of cognitive processes and spatial orientation. Source: compiled by the author.

The control group's results showed that 24 people completed the test task, receiving an indicator of regular coordination. The execution time was 40-50 seconds. Still, there was initial tension and moderate disorientation, quiet commenting on the situation, 9 respondents had difficulty finding the correct numbers, partially the movements were not sufficiently balanced, and several times, there was a violation of the test rules due to concentration on speed rather than quality, in general, there was a pronounced discoordination, fixed execution time 69. This result is probably not a final diagnosis and requires additional research. The respondents, being physically in the research room, could have been concentrating on other topics of their own lives or recently experienced stressful situations, and the factor of social inhibition could have also played a role, as a result of which the activity of the subjects could have decreased due to the presence of other people. The remaining 11 respondents showed a slight discrepancy between visual concentration and spatial orientation. Still, their movements gradually became more balanced and precise without additional pressing on the sheet or violations of the test rules.

It should be noted that the results of the control group cannot be 100% explained by the lack of physical activity and daily non-standard but constant activities that could contribute to brain neuroplasticity, better memory, cognitive function, or motor performance. The findings are likely to be further influenced by exogenous factors related to relationships, professional interaction, or lack thereof, focus on failure, physical fatigue or lack of sleep, and previous trauma. Additionally, a motor sequence test, "Assessment of Motor and Process Skills" was conducted among a group of hockey players to measure the peculiarities of memory, performance skills, functionality, and their changes under the influence of training, which allowed to identify the overall effectiveness of physical activity in promoting brain neuroplasticity. According to the players, they repeatedly suffered bodily injuries, but the severity of these injuries decreased with rehabilitation and the gradual introduction of the loads required by the sport (Figure 2).

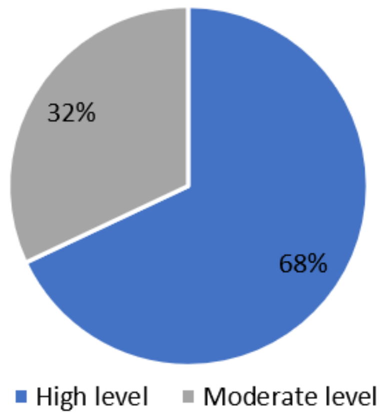


**Figure 2** Indicators of the levels of executive actions during motor activity. Source: compiled by the author.

The high level of performance, which was found in 30 people according to the methodological interpretation, may result from the brain's ability to neuroplasticity, which is facilitated by physical activity and periodic, repetitive actions. This indicator was demonstrated by memorizing and reproducing the proposed movements and body positions in space, and the participants could independently assess the complexity of the task and adapt to its implementation in a short period. A gradual increase in the level of accuracy, faster motor coordination, demonstration of dexterity, and memorization were found. A moderate level of performance was found in 14 people, which indicates some limitations that may be related to various factors: insufficient motor coordination caused by fatigue or disturbed emotional well-being, lack of sufficient training, recent injuries, or chronic illnesses. It is worth noting that such testing is also advisable for sudden injuries, their accommodation, and rehabilitation, which will allow for a better assessment of the human brain's capabilities and its flexibility to negative experiences and obstacles.

## 4. Discussion

The brain's neuroplasticity is one of the exceptional capabilities of the human body, as it allows for development, adaptation, and partial recovery in the event of negative experiences related to organic damage or psycho-emotional disorders, etc. Modern methods and technologies are actively used to visualize the world of the vital organ and its structure to study the brain's neuroplasticity. Neuroimaging techniques are popular, revealing the graphical structure of the brain and helping to observe internal changes. The main ones are functional magnetic resonance therapy, positron emission tomography, and electroencephalography (which studies nerve impulses in epilepsy), which help detect changes in the activity of different brain parts during injury, recovery, or training. Stimulation methods are used to influence brain activity through transcranial magnetic stimulation and transcranial direct current stimulation. Changes in cognitive functions (memory, attention, speech, concentration) can be tracked by psychological tests and tasks based on a comparative analysis of "before" and "after" training or intervention, tracking the dynamics of neuroplasticity and its dependence on the impact of educational factors. Using animal models provides essential information about the molecular, structural, and functional changes during learning, training, or recovery [9, 10].

D. Schwartz and R. Gladding [11] found that brain neuroplasticity is essential in treating obsessive-compulsive disorders due to recursive stimulatory processes (redirection of attention) based on its principles. Researchers also emphasize the importance of developing neuroplasticity through neuropsychoanalysis, which affects the connection between psychological processes and neurological activity of the brain and the redistribution of its functions. The researchers' statements are reasonable since brain neuroplasticity can be developed by integrating neuropsychology, neurobiology, and psychoanalytic concepts to understand the interaction between mental processes and neurophysiological functionality. Psychotherapeutic interventions can affect neural processes in the brain, contributing to changes in mental states and behavior, but their effect may be short-lived and require repeated intervention. For people suffering from mental disorders such as schizophrenia, dementia, and the early stages of Alzheimer's disease, training and various neuroplastic exercises are as important as medication. Training changes the brain's structure and increases its learning capacity so that the cerebral cortex selectively improves its ability to process information, resulting in the brain learning and learning to learn [12].

Exposure to new experiences is used to help clients explore unusual situations on their own and understand thoughts and emotions, and these actions contribute to changes in neural connections. Deficit correction in psychotherapy is used to correct deficiencies in thinking processes, emotional reactions, or behavior. It is also relevant for working with patients with autism, as it stimulates the brain to search for new neural connections and their active functioning. Psychotherapy helps to reconsider one's beliefs and life principles, views and stereotypes, and attitudes towards oneself and others, which also contributes to neuroplasticity activation [13, 14]. E. Hertenstein et al. [15] highlighted the importance of mindfulness techniques, effectively used in psychotherapy to stimulate brain neuroplasticity through traditional meditation, including attentive listening and accepting the present moment without value judgments. This approach encourages a deep focus on one's thoughts, emotions, and body sensations. Practicing mindfulness in the context of brain neuroplasticity can change neural connections, regulate stress, improve attention and cognitive abilities, and relieve emotional stress.

C. Yang et al. [16] investigated changes in brain functional connectivity density (FCD) among athletes engaged in fast-ball sports during initial motor training stages, contrasting with non-athlete controls. The results revealed significant decreases in global functional connectivity density (FCD) within specific brain regions, notably the left inferior frontal gyrus (IFG) and middle frontal gyrus, indicating heightened neural efficiency related to attentional-motor functions in athletes. Furthermore, a correlation was observed between faster executive control reaction time and reduced gFCD values in the left IFG among athletes. These findings suggest that motor training in fast-ball sports can streamline functional connections within the IFG, facilitating accelerated executive control processes.

F. Khan et al. [17] noted that tissue damage to the brain is the initial stage that activates neuroplasticity, which is the key to the successful rehabilitation of patients after stroke. The researchers attributed the early and spontaneous recovery to favorable factors based on training that preserve emotional adequacy, intelligence, and reality in perception. Research suggests that individuals with higher levels of intelligence may experience better recovery after a stroke due to the impact of cognitive abilities on rehabilitation. It has been shown that pre-morbid intelligence quotient and education predict cognition after stroke, with lower intelligence scores and fewer years of education associated with cognitive impairment after stroke.

B.L.J. Kaczmarek [18] noted that neuroplasticity is the ability of the human brain to change throughout life in response to experience, regardless of age. Neuroplasticity preserves the ability to receive and process information but requires new, non-standard skills and abilities that can train it. Activities that involve repetitive mirrored movements, such as martial arts and coordination drills, as well as continuously challenging movement capabilities by acquiring new skills, promote neuroplasticity and skill refinement. Emphasizing sufficient repetition and intensity in training sessions, considering the timing and age of individuals undergoing rehabilitation, and ensuring the transference of acquired skills are also pivotal factors in fostering neuroplasticity and functional outcomes. These principles highlight the importance of active participation, specific training, timing and age considerations, skill transference, feedback, and goal-directed skill development in optimizing neuroplasticity and skill acquisition. The dark side of neuroplasticity is the assimilation of any experience, the inability to switch on the filtering mode to select only helpful information.

The relatively small sample sizes limit the generalizability of the findings. As this was an exploratory study, the effects of potential confounding factors like specific athletic training regimens, academic demands, and personal lifestyles could not be fully controlled. Future research with larger representative samples must confirm and extend these preliminary findings. To identify the impact of training on brain activity, a training program should be developed to focus on the development of specific functions: memory, attention, and motor skills, using brain imaging methods to identify changes before and after training. The test data is a quasi-study and does not carry representative results, as it serves as a current snapshot that situationally determines the likelihood of the impact of physical activity on brain neuroplasticity, functional efficiency, and positive cognitive performance. To avoid stereotypical assumptions regarding the brain's neuroplasticity, long-term studies, and experiments should be conducted comparing the results "before" and "after". An experiment using meditative techniques (meditation may include mindfulness and conscious presence) or other methods to relieve stress and improve cognitive function may be appropriate, which will allow for comparative analysis, both through psychological testing and through the use of magnetic resonance therapy, encephalograms, to track visual dynamics, changes in brain structure, observation of the amplitude of oscillations and neuronal movements that can change under the influence of specific factors.

## 5. Conclusions

The research confirms the positive impact of physical activity and sports on cognitive functions, including memory, attention, perception, and mental flexibility. Professional athletes display more excellent emotional stability than non-athletes, likely due to balanced hormone release during physical activity, which supports brain neuron creation and affects internal chemical compounds. Physical activity enhances brain function, neuroplasticity, and nervous system changes. Novel approaches are needed to unlock the brain's potential for treating complex mental illnesses, oncology, and cardiovascular diseases. This research can inform the development of rehabilitation techniques, especially for stroke patients, by leveraging the brain's compensatory abilities through physical activity and other interventions. Psychotherapeutic approaches such as mindfulness techniques and exposure therapy can enhance brain neuroplasticity, aiding in the treatment of various mental disorders. Engaging in physical activities and learning new skills can also promote brain neuroplasticity, improving cognitive functions and learning capabilities, particularly in early developmental stages.

## Author Contributions

The author did all the research work of this study.

## Competing Interests

The author has declared that no competing interests exist.

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