Psychology and Behavioral Science
International Journal
ISSN 2474-7688

Juniper Publishers
key to the Researchers

Research Article
Volume 22 Issue 4 - December 2024
DOI: 10.19080/PBSIJ.2024.22.556093

Psychol Behav Sci Int J

The Impact of Physical Activity on the Quality of Human Mind Work and Cognitive Processes

Adam Popek*

University of Physical Education in Krakow, Polska

Submission: November 25, 2024; **Published:** December 03, 2024

***Corresponding author:** Adam Popek, University of Physical Education in Krakow, Polska

Abstract

Introduction: Cognitive processes occurring in the nervous system are associated with the acquisition, processing of information from the environment, as well as their use for a specific purpose. The quality and speed of this process will determine the interaction with the environment, and consequently the accuracy of the response to stimuli.

Aim: The aim of the work is to assess the available data in the literature on the effect of physical exercise on mind work and cognitive control.

Material and methods: Analysis of the available literature on the subject, compilation of results and formulation of conclusions on the subject.

Results: Physical activity has a beneficial effect on the volume of selected parts of the brain and the presence of substances in the blood such as BDNF and IGF proteins, which has a positive effect on the quality of cognitive processes occurring in the central nervous system.

Conclusions: Systematically undertaken physical activity can be a means of supporting the quality of the central nervous system, including cognitive control.

Studies show that movement increases the volume of selected parts of the brain and has a beneficial effect on the content of BDNF and IGF proteins in the blood.

Participants subjected to experiments related to undertaking physical activity showed greater effectiveness in solving tests requiring mental engagement and cognitive control, which indicates the beneficial effect of physical activity on cognitive control.

Keywords: Health; Mind; Cognitive Control; Physical Activity

Abbreviations: VEGF: Vascular Endothelial Growth Factor; IGF: Insulin-like Growth Factor; MRI: Magnetic Resonance Imaging; RAVLT: Rey Auditory Learning Test

Introduction

Physical activity has been part of the human genotype since its creation. At the beginning, it involved the need to move for very basic purposes, such as getting food or finding a place to live. The need to provide a certain amount of exercise is also evidenced by the fact that in the case of cessation of activity and at the same time use of muscles, their gradual atrophy is led to. Exercise also has a significant impact on the proper functioning of the circulatory system, improves the overall efficiency of the body, and also brings a number of benefits related to the quality of mind work, improves cognitive abilities, reduces tension caused by stress and improves the level of impulse conduction, which at the same time affects better processing and analysis of stimuli and increases neuromotor abilities. Physical activity in the current times marked by high dynamics and the need for excellent self-organization in the professional and private sphere can play a huge role in the context of maintaining balance. Recreational physical activity, not focused on competition with oneself, not marked by the need to achieve better and better results, is an ideal form of active rest and, contrary to appearances, a source of self-improvement. Although recreational physical activity means taking up movement, activity, due to the way of perception, the time devoted to it is characterized by subjective slowing down and detachment from routine duties. As it turns out, a number of positive changes take place in the nervous system, where cognitive abilities improve, influencing better information acquisition, learning, as well as analytical and future thinking.

Materials and Methods

Physical activity can be a sphere considered from the level of social and neurobiological effects. The cognitive function responsible for processing information and coming from the external environment and somehow filtering them, decides what will be assimilated, to what extent, and then we can consider another sphere related to their use. From the point of view of health, physical activity seems to be a necessary element of everyday life. The latest National Health Test informs that over half of Poles do not engage in physical activity at all, and the average BMI is 26.7, which means overweight. A high percentage of weight problems is observed already at the primary school level, so we can talk about a negative trend when it comes to basic health care. Excessive weight gain, unfavorable body composition, increased amount of fat tissue, LDL cholesterol inhibit motor skills, the quality of the nervous system, burden the heart and reduce efficiency. The best form of counteracting such degenerative changes caused by, among others, a sedentary lifestyle and emerging stress is regular movement. Cognitive abilities themselves can be assessed as an internal image of the world, influencing the attitude to the environment and determining the interactions undertaken. In order to make this picture as complete as possible, the efficiency and engagement of the senses are necessary, which can be described in general as sensory. Next, attention is distinguished, as the ability to select stimuli from the environment, i.e. to choose or reject specific information. It is worth emphasizing that without concentration on a specific stimulus, information, the ability to remember would not be possible. Memory, in turn, is the ability to store information. First, short-term memory associated with a specific stimulus must occur, and then it can pass into long-term memory. Memorization is aided by an emotional stimulus. It can be positive or negative, but its strength will interact with the information being acquired and influence whether it will be remembered in the nervous system.

The consequence of memory is a higher quality of logical thinking, i.e. reasoning, where we use the information we have in a purposeful and directional way. The brain is made up of neurons and glial cells. The latter mainly perform metabolic and structural functions. Neurons are the most important cells, whose main task is to send signals. Specifically, these are neurochemical impulses that enable reactions to occur in other structural elements of the body. No reaction will occur without appropriate stimulation. Cells communicate with each other using synapses, and it is estimated that there are about 100 trillion of them in the human brain. It is worth emphasizing that synapses are modifiable in relation to the transmitted signal. This means that they are able to change the strength of the signal through the signal patterns that pass through them. It is this mechanism, i.e. modification in relation to the stimulus, that is considered the learning pattern. Physical activity primarily brings benefits related to the level of brain cell congestion, nutrition, oxygenation and stimulation other than that resulting from, for example, routinely performed duties. In addition, in the context of learning, an important role is played by a substance called BDNF, or Brain-Derived Neurotrophic Factor. It is a protein secreted by neurons and is a nerve growth factor. It also plays an important role in synaptic plasticity, i.e. the aforementioned ability to adapt and change synaptic connections in response to stimuli, learning. It turns out that a significant increase in the concentration of this protein occurs in the case of aerobic exercises, of higher intensity and of a systemic nature. This allows us to conclude that physical activity develops the nervous system and significantly affects the development of the process of memorization. At the same time, such significant changes were not observed in the case of anaerobic exercises, which in turn draws attention to the fact that the duration of the exercises is also important. In the structure responsible for memory, i.e. the hippocampus, the level of BDNF was higher the longer the exercise time. Anaerobic exercises are short-term exercises [1].

Among the beneficial effects resulting from the presence of BDNF, there is the inhibition of apoptosis in neurons and a reduction in the sensitivity and damage of nerve cells caused by oxidative stress. Indirectly, a reduced level of BDNF has a degenerative effect on the nervous system, which can lead to dementia, neuropsychiatric and neurodegenerative diseases. In addition, studies have shown that BDNF levels are reduced in patients with schizophrenia in the area of the brain associated with working memory [2-4]. It is worth adding that the BDNF protein is also located in, among others, the heart muscle, skeletal muscles and lungs. One of the functions is to contribute to the development of stem cells, and due to its properties, also to cell regeneration [5,6]. Indirectly, the vascular endothelial growth factor VEGF, which takes part in the formation of new blood vessels and in building blood circulation, may be involved in improving neurological functions. water, which allows for better nutrition and delivery of essential components to nerve cells. Studies have shown an increase in VEGF concentration, especially after intensive exercise. Another component that contributes to the improvement of neurological functions is insulin-like growth factor IGF-1. This is a protein hormone involved in the growth of tissues and bones.

People who regularly perform aerobic exercise (e.g. fast walking - Nordic walking, swimming, running, rollerblading, cycling) achieve better results in neuropsychological and performance tests that measure specific cognitive functions, such as visual control, cognitive flexibility, updating and capacity of working memory, parameters of declarative memory, spatial memory and information processing speed [16,17]. Aerobic exercise is also a strong antidepressant and euphoric "agent" [7], therefore, when consistently undertaken, it causes a general improvement in mood and self-esteem [20]. Interesting conclusions emerged after conducting a 6-month study on 86 randomly selected women aged 70-80 with subjective statements of abnormalities

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in the functioning of the memory sphere. They were classified into groups: resistance training, aerobic training, control group. All participants performed the recommended exercises twice a week for six months. Verbal memory and the learning aspect itself were assessed using the Rey Auditory Learning Test (RAVLT), as well as spatial memory tested using a computerized test, performed before and after the study [8-10]. It was found that the aerobic training group remembered significantly more items after the RAVLT, compared to the control group after six months. In addition, both experimental groups showed improvement in spatial memory in conditions where it was required to remember the location of three items, compared to the control group [11-14]. Other studies have shown that regular aerobic exercise increases the volume of the hippocampus, the brain region where the memory center is located. Resistance training, balance training, and muscle strengthening exercises did not produce the same results. The benefits of exercise are directly due to the mechanism of reducing insulin resistance and stimulating the release of growth factors-chemicals in the brain that affect the health of brain cells, the growth of new blood vessels in the brain, and the survival of new brain cells. Indirectly, exercise improves mood and sleep, reduces stress and anxiety, and problems in these areas often cause cognitive impairment [15].

In Stockholm, it was shown that aerobic training performed during running not only increased the volume of the hippocampus, but also had an antidepressant effect, which correlates with the previously presented set of information about neurotransmitter activation in the brain [15,16]. According to research conducted by the Department of Exercise Science at the University of Georgia, even short exercises lasting 20 minutes improve information processing and memory functions [16]. In the context of development, UCLA studies have shown that exercise increases growth factors in the brain, which helps the brain create new neural connections [17]. As it turns out, exercising people increase the area not only of the central cortex of the brain, where memory is located, but also of the frontal cortex, responsible for constructive, logical thinking. This last aspect also plays a huge role in sports, especially in team games, where it is required to undertake not only physical effort, but also to combine technical elements, analyze the behavior of the opponent and partners on the field, and implement the chosen strategy during competition. Many other studies confirm that the parts of the brain that control thinking, and memory (prefrontal and central cortex) have a larger volume in exercising people, compared to people who do not engage in physical activity. It is postulated that any form of exercise that has a holistic effect on the circulatory system will hide such properties [18].

The studies also provided information proving that in older people there was a positive correlation between the volume of the hippocampus and the efficiency of cognitive processes [19]. Erickson et al. [20,21] tested 165 healthy individuals aged 59 to 81 years. Their cardiorespiratory fitness was assessed using exercise testing and hippocampal volume was measured using magnetic resonance imaging (fMRI) while performing spatial memory tasks. The results showed that higher fitness was associated with larger hippocampal volume, which in turn was associated with better spatial memory performance [22,23]. Considering that the hippocampus in shows degenerative changes during the aging process, these findings indicate that aerobic fitness can be an effective means of preventing negative factors related to age and cognitive impairment [24]. Based on the results of the study [25] of 120 elderly people, it was found that the study group undertaking physical activity had a 2% increase in hippocampal volume. In addition, this group showed higher levels of BDNF in the blood and improved spatial memory. The control group did not show such changes in brain structure and cognitive structure efficiency, thus providing further evidence that physical training increases hippocampal volume in late life and has a positive effect on maintaining the highest possible quality of processes involving the memory sphere [26]. Another particularly important study [27] was the assessment of the role of exercise in the process of neurogenesis in the hippocampus using a study group consisting of humans and mice. Two magnetic resonance imaging (MRI) studies were conducted, with the first analysis imaging the volume of cerebral blood in the hippocampus structure during exercise in mice. The results showed increased cerebral blood volume in the dentate gyrus, a region of the hippocampus that has been shown to support neurogenesis in adults. This increase was subsequently found to correlate with the neurogenesis seen after training [22].

The second study measured cerebral blood volume in adult humans (average age 33 years) after 12 weeks of aerobic exercise training, a performance-based exercise. Similar to the mouse model, exercise had an effect on the dentate gyrus, with cerebral blood volume correlated with cardiorespiratory fitness [22]. These results were further supported by improved cognitive performance on the Rey Auditory Learning Test, which was also associated with cardiorespiratory fitness and cerebral blood volume [22]. These data suggest that within the hippocampus, the dentate gyrus is uniquely responsive to stimuli, and that increased activity associated with exercise affects neurogenesis. In addition, the level of BDNF is closely related to the larger volume of the hippocampus, which has been noted to affect the learning process and memory [20]. Thanks to advances in the aforementioned neuroimaging techniques, awareness of the impact of aerobic exercise on the structure and function of the brain has grown rapidly over the last decade. In particular, a series of studies [20] were conducted in older people to better understand the relationship between aerobic brain performance and cognition. Aging causes brain tissue degeneration, with a clear loss of tissue functionality demonstrated in the frontal, temporal and lateral lobes [24]. Therefore, it is postulated that the cognitive abilities for which the aforementioned brain regions are responsible significantly deteriorate in comparison with other aspects of mental functioning. In particular, the age-related decrease in gray

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matter volume caused a decrease in various processes classified as cognitive control. This was associated with, for example, a greater number of errors in the Wisconsin Card Sorting Test [25] and better memory encoding during the study of language learning from listening. The reduction in gray matter volume may be due to several factors, including the loss of neurons, shrinkage of neurons. In addition, aging results in a reduction in the amount of white matter, which affects the transmission of information between neurons. The loss of white matter volume is associated with decreased performance in many cognitive tasks [27] and may be due to demyelination of axons, reducing the rapid and efficient flow of signals through the nervous system. However, based on the results of animal studies, as well as the effects of aerobic exercise on cognitive control observed in studies, scientists speculate that an active lifestyle may serve to maintain efficiency in brain regions that support cognitive control.

Interestingly, these studies have shown similar benefits of exercise for maintaining brain health in people with various diseases, including dementia, Alzheimer's disease, and schizophrenia [28,29]. Referring to the nature of the effort and dividing it into aerobic and anaerobic, it should be mentioned that the results of the conducted studies indicate that an increase in the volume of selected parts of the brain, an increase in the amount of gray and white matter in adults occurred in the case of strength training. However, no such findings were found in the elderly group undertaking anaerobic exercise and in the control group [28]. In particular, people assigned to the aerobic exercise group showed an increased amount of gray matter in the frontal lobes, an increased area of the brain responsible for motor skills, and increased efficiency of the cerebral circulatory system. Positive changes also occurred in the temporal lobe [28]. The influence on the structure of the brain also results from another action. Most of the genes regulated after exercise are associated with the functioning of BDNF and IGF systems. Given the strong involvement of BDNF in neuronal excitability and synaptic function, the results seem to indicate a dominant effect of BDNF on the brain region during exercise [29]. It has been shown that longer exercise gradually increases BDNF levels and makes the BDNF effect also take place several hours after the end of exercise. To assess the effect of exercise on the neurological sphere, the effect occurring in the period after the end of exercise should be taken into account. A study of BDNF action on the hippocampus after 3 weeks of exercise showed the highest BDNF concentrations immediately after the exercise period, moderate 2 weeks after the end of exercise, and the return to the baseline level took 3 to 4 weeks. Moreover, earlier exercise seems to provide a basis for easier elicitation of the body's response to exercise undertaken later in life. Moreover, if a person is adapted to physical effort, they will more easily obtain a higher concentration of the BDNF substance in the case of the next training session [19]. Many studies over the last decade have shown that exercise is the strongest promoter of neurogenesis in the brain of adult humans, but also rodents, which has led to the conclusion that the process of neuronal development may contribute to the development of the cognitive sphere observed during exercise. In addition to the BDNF substance itself, the actions of IGF-1 and vascular endothelial growth factor (VEGF) are considered important for the angiogenic and neurogenic effects of exercise in the brain. Although observations on brain angiogenesis have been known for many years, only recent studies of the hippocampus have been associated with cognitive function. In addition, factors induced by exercise, such as BDNF, may also facilitate the functioning of synapses and affect other aspects of neuronal plasticity [29].

Conclusions

a) Physical activity, also undertaken for recreational purposes, has a number of positive properties in the context of the speed of mental work, improves the quality of cognitive processes, learning, and also prevents aging.

b) Studies show that exercise increases the volume of selected parts of the brain and also has a beneficial effect on the content of BDNF and IGF proteins in the blood.

c) Participants subjected to experiments related to undertaking physical activity showed greater effectiveness in solving tests requiring mental engagement and cognitive control, which indicates the beneficial effect of physical activity on cognitive control.

Summary

Regular physical activity has a number of effects on the central and peripheral nervous system. One of the most important is the improvement of the quality of cognitive processes, which translates into a person's relationships with the world, the speed and quality of learning, and the ability to engage in new interactions. Thanks to mental fitness and its maintenance for longer years, physical activity can counteract the aging process and other dysfunctions resulting from the lack of proper use, as well as the activation of nerve cells. Physical activity, especially recreational activity, is undoubtedly an excellent and free way to improve one's own health, including mental health.

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