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Research Paper

Effects of Physical Exercise on Neuroplasticity and Cognition in the Human Brain

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ABSTRACT

Various studies over years have been investigating the positive effects of physical exercise on people's health and lifestyle. However, apart from the health benefits, exercising regularly contributes to various positive changes in the human brain. These changes include structural, functional, and cognitive changes. Clinical research has found that physical exercise can reduce cognitive decline related to age, apart from medical conditions counting type II diabetes, heart diseases, obesity, and cancers. During the process of neuroplasticity, these neurotrophins create variations in the growth and differentiation of cell signaling. Throughout life, events and experiences contribute to changes in the structure and function of the brain, and this change is observed in various parts of the brain. Therefore, this essay will focus on the effects of physical exercise on structural, functional, and cognitive functions in the brain.

Keywords: *Physical Exercise, Neuroplasticity, Cognition, Human Brain*

Physical exercise contributes to positive changes in the brain. The World Health Organization (WHO) defined physical activity as any bodily movement through skeletal muscles that requires energy expenditure (WHO review 2022). Physical activity therefore involves daily activities including sports, and physical exercise. Physical exercise is defined as an activity with the purpose of improving fitness and health (Adam et al, 2006). Various studies over years have been investigating the positive effects of physical exercise on people's health and lifestyle. However, apart from the health benefits, regular exercise contributes to various positive changes in the human brain including structural, functional, and cognitive changes. Clinical research has reported that physical exercise can reduce cognitive decline related to age, apart from medical conditions counting type II diabetes, heart disease, obesity, and cancers (Chieffi et al., 2017). Various neuroimaging studies have found structural and functional modifications in the brains of people who exercise regularly, which contributes to specific cognitive changes in the human brain (Chieffi et al., 2017). The term neuroplasticity or neural plasticity is a process that occurs in the brain and is responsible for adaptive functional and structural changes caused by external or internal stimuli. This process involves reordering the structure, functions or connections following specific injuries to the brain for instance traumatic brain injury (Puderbaugh &Emmady, 2022). Neurotrophins are proteins that regulate survival, development, and functionality of the central and peripheral nervous systems (Kozorovitskiy & Gould, 2010).

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During the process of neuroplasticity, these neurotrophins create variations in the growth and differentiation of cell signaling (Fernandes et al., 2020). Throughout life, events and experiences contribute to changes in the structure and function of the brain, and this change is observed in various parts of the brain (Glasper & Neigh, 2019). This paper aims to recapitulate the effects of physical exercise on structural, functional, and cognitive functions in the brain.

Regular physical exercise benefits brain structure. Various studies have documented structural changes in the brain following physical exercise. These structural changes mainly occur in regions of the cerebellum, hippocampus, and cerebral cortex (Erickson et al., 2009). In 1999, a study recorded an increase in the number of neurons in the hippocampus, a region in the brain responsible for memory and stress regulation, of mice. Later the researchers confirmed the correlation of this information with an increased cerebral blood volume (CBV), which is measured using magnetic resonance imaging (MRI) (Erickson et al., 2009). In 2009, Erickson and his colleagues conducted a study representing a correlation between the volume of the hippocampus of older adults, and cardiovascular fitness through the volume of consumption of oxygen in the participants (VO2). Later in 2011, Erickson and colleagues observed that a year-long regular exercise increased the volume of the participants' hippocampus by 2% in older adults (Erickson et al., 2009). Furthermore, Bashir and colleagues investigated healthy male participants aged between 19 and 27 years, who were initially divided into experimental and control groups. Participants in the experimental group were engaged in various types of physical exercise including walking, cycling, muscle training, and so on. Whereas participants in the control group were not involved in any physical exercise. The results of the study reported that participants in the experimental group showed increased fractional anisotropy (FA) in the left frontal white matter. This record indicated increased brain connectivity in healthy male participants. Additionally, the researchers suggested an hour-long exercise daily for around six months will enlarge white matter in the brain, making the communication between the cerebral hemispheres more efficient. (Bashir et al., 2020).

Functions in the brain are modified by physical exercise. Changes in the hippocampus, a part of the brain responsible for learning and memory, through modifications in the gene expression, are recorded due to physical exercise (Cotman & Engesser-Cesar, 2002). Physical exercise, especially aerobic physical exercise enhances blood flow and vascularization resulting in a better supply of oxygen and nutrition in the brain. Older adults who exercise regularly have more small cerebral vessels compared to older adults who do not exercise (Hötting & Röder, 2012). Experts have used various brain scans including functional magnetic resonance imaging (fMRI) to trace functional changes in the brain after physical exercise. The results of the brain scans demonstrated an increased neuronal efficiency during executive and memory tasks (Hötting & Röder, 2012). Further research suggests resistance exercises and resistance training lead to functional brain changes in parts of the brain including the frontal lobe (Herold et al., 2019). However, further studies are needed in this field to investigate specific mechanisms. Moreover, the studies suggest physical exercise affects baseline electrocortical functions which may eventually influence the cognitive functions of the brain (Hillman et al., 2008). Additionally, older adults who were asked to participate in the walking intervention showed increased activation in the middle frontal gyrus and superior parietal cortex (Hillman et al., 2008). Physical exercise activates the interaction of signaling that affects plasticity of the brain, enhances cognitive functions, and improves cerebrovascular perfusion (Cotman et al., 2007). Thus, regular physical exercise ensures stronger brain functions.

Physical exercise prevents cognitive decline in older adults. Experiments conducted by Yaffe et al., and Niemann et al., conclude that participants who underwent physical exercise portray a relatively slower cognitive decline and limited risk of dementia (Yaffe et al., 2009; Niemann et al., 2014). Various studies in the field have supported the concept that physical exercise acts as a moderator of cognitive decline related to age. Previous studies that have compared younger adults to older adults concluded that physical exercise including cardiorespiratory fitness leads to efficient cognitive functions (Bherer et al., 2013). Older adults from various European countries including, Sweden, Denmark, Switzerland, the Netherlands, Belgium, France, Spain, Italy, and Greece were invited to participate in the experiment that reported, individuals who engaged in any type of regular physical activity showed a lower cognitive decline after 2.5 years (Bherer et al., 2013). Systematic reviews conducted online investigated the relationship between increased physical exercise following stroke. The benefits of physical exercise were also recorded to reduce depressive symptoms in the participants and encourage better cognitive performance (Cumming et al., 2012). Further studies investigating the intervention between physical exercise and cognitive functions suggest that physical exercise provides protection against cognitive impairment and dementia in older adults (Singh-Manoux et al., 2005). Research conducted by Kirk-Sanchez and McGough suggests that based on the evidence collected from previously conducted studies, individuals who engage in physical exercise in their midlife and late life have a considerably lower risk of developing global cognitive decline and dementia. The intensity of physical exercise can significantly cause changes in the cognitive performance of people in domains including attention, memory, and executive functions (Kirk-Sanchez & McGough, 2022). In addition to adults, children too improve their cognitive functions through physical exercise. Children who are reported to engage in physical exercise perform better on verbal, perceptual, and mathematical tasks (Fernandes et al., 2017). Moreover, studies also suggest that regular physical exercise at home including balancing on one leg, spinning, standing on a wobble board, tandem walking, and throwing and catching balls result in improved reading accuracy, phonemic abilities, and verbal working memory in school children (Poloughman, 2008). Therefore, physical exercise not only benefits cognitive functions in adults but also helps children enhance their academic performances.

CONCLUSION

Physical exercise positively impacts the structural, functional, and cognitive changes in the brain. Structural changes in the areas including the cerebellum, hippocampus, and cerebral cortex undergo various neural regulations. Functional changes caused by physical exercise in the brain also help regulate various cognitive functions associated. These changes occur in different age groups including children, younger, as well as older adults, and contribute to enhancing cognitive functions in them. However, further research in the field investigating more gene expression associated with functional changes, and identifying additional benefits of exercise on executive functions is required. Following a routine of physical exercise provide cognitive benefits to people and reduces risks of neurological disorders.

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Conflict of Interest

The author(s) declared no conflict of interest.

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