Impact of Physical Exercise on functions of Human CPU - the Brain

Nasir-uddin KHAN
University of Karachi

Mushtaq HUSSAIN
Newports Institute of Communications and Economics, Karachi.

Khair un Nisa KHAN
University of Karachi

Muhammad SHAHID
University of Karachi

M Usman Ghani KHAN
Ziauddin University

Abstract

Brain plays a vital role in our daily life. It controls each and every function of a human body, as it is said that brain is the boss. Healthy brain is a blessing from God. Some human behaviors, environmental and social conditions put an adverse effect on human brain and its abilities. Today humanity is facing various brain diseases and psychological problems. In the last few decades, some research has been done on brain problems their causes and preventions. Studies show that there are many human behaviors which are harmful for brain health and there are also some preventive steps which we can opt for reducing the risk of brain and mental problems. One of them is doing physical exercise regularly. Regular physical exercises not only strengthen our body it also give boost to

our brain power. Physical exercises, especially aerobic, play a beneficial role in neurogenesis and proliferation of nerve cells. It also reduces the effects of many human behaviors which are harmful for brain health. But many people are unaware of the benefits of physical exercise on brain health. In this paper, the important role of physical exercise in the brain health will be discussed.

Keywords

Physical Exercise, Brain health, human behaviors, Brainderived neurotrophic factor (BDNF).

1 Introduction:

Brain is a very complex but the most important organ of human body. It consists of billions of cells which are connected to each other by synaptic connections. Brain cells enable us to think, feel, learn, memorize and to do any action. Human brain is organized in such a way that specified areas are responsible for specific functions. The motor areas are responsible for the movement of our body parts, sensory areas are the locations for sight, hearing, smell and other senses. Some areas perform complex functions like emotions, thinking, learning and memorizing. The brain's functions are very similar to the functions of a CPU- Central Processing Unit, of a computer. A computer receives data through input devices, the data is processed by the CPU, and we get output through output devices. Similarly, our brain receives messages (or data) through sensory system, processes it and gives commands to rest of our body through motor nerves. Just like a CPU to a computer, our brain is vital to our body. A computer is useless without a CPU, so

is our body without our brain. Therefore, a healthy brain is very important to live a happy and successful life.

Some human behaviors are effecting this remarkable creation of nature badly. Due to lack of awareness and some other factors such as environmental, social and economical conditions, brain diseases and psychological problems are increasing in Pakistan. We all know that our brain controls our behaviors, but we know very little that our behaviors affect our brain too. Depression, anxiety and stress are the main causes which harm the brain most. Untreated depression, prolonged anxiety and uncontrolled stress put a very bad effect on neurogenesis (creation of new brain cells) and proliferation of brain cells. In the 1990s, researchers found that neurogenesis was primarily occurring in the hippocampus which is also the area of the brain related to memory and learning abilities. According to NHS-England, patients who consult general practitioner about memory loss are most likely to have anxiety, stress and depression. Lack of sleep put a negative effect on brain. Both quality and quantity of sleep are important for brain health. Studies showed hippocampus neurogenesis and proliferation were impaired by sleep deprivation. Excessive alcohol use has been considered as a cause of memory loss. Smoking harms brain by reducing the amount of oxygen going to the brain. Illicit drugs can bring chemical changes in the brain which can be very harmful. High blood sugar, high blood pressure and high cholesterol are also the risk factors for brain. They not only put an adverse effect on over all brain health but can also cause stroke. These are some destructive behaviors for brain health. On the other hand, regular physical exercise is a constructive behavior for keeping healthy brain. Especially aerobic exercises can be really beneficial for brain. It is useful for young adults as well as children and elders. Many of us know the benefits of exercise on our body health but most of the people are unaware of the positive effects of physical exercise on brain health. In this paper, important role of physical exercise on brain health and its abilities will be presented.

Effects of Physical Exercises on Brain Health:

Physical exercise plays an important role in brain functions by many ways from physiological to behavioral aspects. Physical exercise puts a positive impact on our brain's growth, its abilities and functions. It also plays a therapeutic role in different brain disorders and psychological problems. Physical exercise is beneficial for children, adults as well as aged people.

Role of Physical Exercise in Brain Growth:

Physical exercises increase the supply of blood thus supply of oxygen to the brain. It also helps the secretion of plenty of beneficial hormones which provide a nurturing environment for the growth of the brain cells.Studies showed that the human hippocampus retains its ability to generate neurons throughout life [2]. Brain-derived neurotrophic factor (BDNF) is very important for the brain growth. Studies showed that the expression of BDNF is increased after voluntary exercise. Physical exercise stimulates growth of neurons in multiple aspects. Regular physical exercise increases neurogenesis, proliferation of nerve cells and brain plasticity (the ability of the brain to develop new neural connections). A study on mice found out that running doubled the number of surviving newborn cells, in amounts similar to enrichment conditions. Its findings demonstrate that voluntary exercise is sufficient for enhanced neurogenesis in the adult mouse dentate gyrus [3]. Other studies on rats showed that treadmill exercise enhanced neurogenesis and cell proliferation [4,5]. Another study demonstrated that voluntary exercise increases the growth of new connections in nerve cells and enhances nerve regeneration after nerve injury. Same study suggested that capacity for axonal outgrowth increased with longer periods of exercise [6].

Physical Exercise - A Remedy for Behavioral Disorders:

Physical exercise helps to cope with depression, anxiety, stress and sleep disorder. Neurotransmitters play key role in human behaviors. Serotonin is linked to sleep and emotion, dopamine causes extreme happiness, epinephrine is released during fear and anxiety and norepinephrine is linked to happiness and sadness [7]. Scientist found that depression, anxiety, stress and sleep disorder are linked to a chemical imbalance (of these neurotransmitters) in the brain. Depression is related to low levels of serotonin and norepinephrine. Physical exercise affects like an antidepressant and helps to restore the chemical balance in the brain. Exercise increases concentrations of these neurotransmitters by stimulating the sympathetic nervous system. Exercise increases stress resilience and reduce anxiety. Studies suggest that aerobic exercise (55-70% VO2 max) elicits not only decrease in negative feeling states (state anxiety) but also increases in positive effects [8]. Further, physical exercise reduces the harmful effects of these behavioral disorders on brain. The reason is increased expression of BDNF by physical exercise which increases the neurogenesis. A study on rats showed that treadmill exercise ameliorated post-traumatic stress disorder - induced memory impairment through enhancing cell proliferation in the hippocampus [5]. Another study on rats showed that due to prenatal stress, offspring showed suppressed neurogenesis in the hippocampus but postnatal treadmill exercise lessens prenatal stress-induced deterioration of brain function in off spring [4].

Physical Exercise Improves Memory and Learning Abilities:

Regular physical exercise especially aerobic exercise improves memory and cognitive abilities. Exercise has multiple effects on memory and learning. BDNF promotes synaptic plasticity which plays a basic role in memory and learning. A study suggests that light and moderate exercises improve cognitive function across the adult lifespan

[9]. Regular physical exercise increases neurogenesis in the hippocampus which is the area of brain associated with memory and learning abilities. A study on monkeys suggests that regardless of the age of the monkeys, monkeys on the running regimen (1 hr a day, 5 days a week for 5 months) learned new things almost twice as fast as the sedentary animals [10]. A study on adult male concluded that a single bout of moderate intensity aerobic exercise for as less as 30 minutes can improve some aspects of cognition, most prominently for memory, reasoning and planning and can shorten the time taken to complete the tests [11]. Even 15 minutes exercise (moderate intensity) is associated with important benefits for both affective experience and cognitive performance (reaction time for working memory) regardless of age [12]. Many studies show a positive correlation between physical activity and learning abilities in children.

Physical Exercise Reduces Risk Factors for Brain Health:

Smoking, high blood pressure, high level of blood sugar and cholesterol are enemies of our body health especially arterial health. The factors that are harmful for arteries are also risk factors for our brain health. A diet consisting of high saturated fats and sugar decreases the neurogenesis. These factors not only put an adverse effect on over all brain health but are causes of stroke too. Physical exercise helps to minimize these risk factors and their bad effects. Studies showed that exercise helps to quit smoking if someone wants to do it.

Results of a study suggest that aerobic exercise has potential as a smoking cessation treatment, but that it must be engaged in frequently and consistently over time in order to derive benefits [13]. Exercise reduces chances of silent stroke by 40%. According to a study baroreflex dysfunction, oxidation stress and inflammation, important hallmarks of hypertension, are attenuated by exercise training. Studies indicate that training promptly restores baroreflex function and blood pressure fall occurs [14]. Another study proposed that an awareness of

the exercise intervention benefits of pre- and post stroke may lead more stroke patients and people with high risk factors to accept exercise therapy for the prevention and treatment of stroke [15].

Physical Exercise is Beneficial in Brain Diseases and Psychiatric Disorders:

Regular physical exercise plays preventive as well as therapeutic role in many neurological and psychiatric disorders.Alzheimer's Disease (AD) is a cortical neurodegenerative disorder that progresses over time and is the most common form of dementia. A literature review found that AD individuals who included physical activity in their daily lives would reduce cognitive decline and improve psychological and/or physical performance, as well as mobility, balance, and strength [16]. A study showed that exercise plays a role in decreasing the risk of developing AD [17]. A study found out that physical activity reduces hippocampal atrophy in elders at genetic risk of Alzheimer's disease [18]. Huntington's Disease (HD) is a genetic neurodegenerative disorder leading to a decline in motor skills, chorea, sub-cortical dementia, and other psychiatric symptoms. A study on mice models of HD showed that exercise delayed the onset of symptoms and slowed cognitive decline [19]. There is no cure for AD and HD, only symptoms and conditions associated with these diseases can be improved. Parkinson's disease (PD) is a neurodegenerative disorder with symptoms such as deficit cognition, rigidity and shaking in movement, and impaired gait. In a study on participants with early-to mid-staged PD, individuals performed 20 minutes of aerobic exercise three times a week for 8 weeks on a stationary exercise cycle. It was found that aerobic exercise improved several measures of cognitive function in patients with PD [20]. Attention deficit hyperactivity disorder (ADHD), is a neurological/behavioral condition resulting in hyperactivity and the inability to focus on tasks. Results of a study suggested that treadmill exercise might exert ameliorating effect on

ADHD through reduction of Purkinje cell loss and astrocytic reaction in the cerebellum [21]. Autism is a complex neuro-developmental disability with impairments of social interaction and communication, and repetitive behavior. A study showed that treadmill exercise ameliorated aggressive behavior and improved spatial learning memory in autistic rats [22]. Schizophrenia is a serious psychiatric disorder with several symptoms including cognitive dysfunction. A study demonstrated that treadmill running improved schizophrenia-related parameters [23].

Effect of Physical Exercise on Elders and Children:

Besides young adult, physical exercise is beneficial for elders and children too. As someone grows older, some areas of brain shrink naturally. Besides neurogenesis, BDNF has protective and restorative role on neurons too. Increased expression of BDNF, due to exercise, slows down the age related shrinkage of brain. A study suggests that increased cardiovascular fitness can affect improvements in the plasticity of the aging human brain, and may serve to reduce both biological and cognitive decline in humans [24]. Those behaviors that enhance dendritic complexity and synaptic plasticity also promote successful aging and decrease risk of neurodegenerative disorders [25]. Regular exercise can promote maintenance of cognitive function during aging [26]. Aerobic exercise is more effective to brain health than strengthening exercises for elders. A study on older adults showed that after 6 months exercise regime, aerobic group demonstrated a significant increase in cardiovascular fitness, a reduction in behavioral conflict from time 1 to time 2, a significantly greater level of task-related activity in attention control areas as compared to the other group (participants of other group were assigned stretching and toning exercise) [27]. Results of a study indicated that regular and chronic aerobic exercise has time and dose-dependent, neuro-protective and restorative effects on physiological brain aging, and reduces anxiety-

related behaviors [28]. A study found that mild-intensity exercise program increased muscle oxygen consumption by soleus and heart in aging rats and reversed age-related long-term spatial learning and memory impairments [29]. One year of aerobic exercise in a large RCT (randomized controlled trial) of seniors was associated with significantly larger hippocampal volumes and better spatial memory; other RCTs in seniors documented attenuation of age-related gray matter volume loss with aerobic exercise [30]. Physical exercise puts positive effects on brain performance of children. A meta-analysis concluded that there is a significant positive relationship between physical exercise and cognitive functioning in children. The results of this analysis suggest that physical exercise may be related to improved cognitive performance and academic achievement [31].

3 Results/Discussion

Brain is most powerful but at the same time very fragile organ of human body. Healthy brain is essential for a lucrative life. In fact, healthy brain and healthy body both are very important for a successful life. Healthy brain and healthy body put reciprocal effects on each other i.e. healthy body keeps healthy brain; and brain health is required for healthy body. Physical exercises play a very important role in brain health as well as body health. Regular physical exercises, especially aerobic exercises, not only prevent brain problems and their risk factors but also provide cure to some extent. Further, it is the simplest, easiest and inexpensive way to cut the chances of getting brain diseases and psychological disorders. A person can get benefits from even a 15 minutes' walk and the positive effects goes on with the increase in time. Young adults, elders and children can achieve remuneration from physical exercise.

4 Conclusion:

Regular physical exercise benefits our brain and body. Physical

exercises, especially aerobic exercises, put preventive as well as therapeutic effects on our brain. Regular physical exercise leads to a happy childhood, successful adulthood and finally a satisfied aging.

References:

[1]. Babsky. E, Khodorov. B, Kositsy. G, Zubkov. A. Human Physiology (Vol 2). Moscow, Russia: Mir Publishers, 1985

[2]. P, Eriksson Perfilieva E, Björk-Eriksson T, Alborn A, Nordborg C, et al. Neurogenesis in the adult human hippocampus. Nature Medicine 1998; 4: 1313-1317.

[3]. Van Praag H, Kempermann G, Gage F. Running increases cell proliferation and neurogenesis in the adult mouse dentate gyrus. Nature Neuroscience. 1999; 2: 266-270.

[4]. Kim TW, Shin MS, Park JK, Shin MA, Lee HH, et al. Treadmill exercise alleviates prenatal noise stress-induced impairment of spatial learning ability through enhancing hippocampal neurogenesis in rat pups. Journal of Exercise Rehabilitation 2013; 9(5): 451-6.

[5]. Kim BK, Seo JH. Treadmill exercise alleviates post-traumatic stress disorder-induced impairment of spatial learning memory in rats.Journal of Exercise Rehabilitation. 2013; 9 (4): 413-9.

[6]. Molteni R, Zheng JQ, Ying Z, Gómez-Pinilla F, Twiss JL. Voluntary exercise increases axonal regeneration from sensory neurons. Proceedings of the National Academy of Sciences USA. 2004; 101(22):8473-8.

[7]. Susan. D. Bipolar Disorder and Dipression. New Jersey, USA: Enslow Publishers, Inc.,2000

[8]. Tate AK, Petruzzello SJ. Varying the intensity of acute exercise: implications for changes in affect. Journal of Sports Medicine and Physical Fitness. 1995; 35(4):295-302.

[9]. Kamijo K1, Hayashi Y, Sakai T, Yahiro T, Tanaka K, et al. Acute effects of aerobic exercise on cognitive function in older adults. Journal of Gerontology Series B Psychological Sciences and Social Sciences. 2009; 64(3):356-63.

[10]. Rhyu IJ, Bytheway JA, Kohler SJ, Lange H, Lee KJ, et al. Effects of aerobic exercise training on cognitive function and cortical vascularity in monkeys. Neuroscience. 2010; 167(4):1239-48.

[11]. Nanda B1, Balde J, Manjunatha S. The Acute Effects of a Single Bout of Moderate-intensity Aerobic Exercise on Cognitive Functions in Healthy Adult Males. Journal of Clinical and Diagnostic Research. 2013; 7(9):1883-5.

[12]. Hogan CL, Mata J, Carstensen LL. Exercise holds immediate benefits for affect and cognition in younger and older adults. Psychological Aging. 2013; 28(2):587-94.

[13].]Williams, Shira D, Jessica AW, Michael HU, Joseph TC. Acute Effects of Moderate Intensity Aerobic Exercise on Affective Withdrawal Symptoms and Cravings among Women SmokersDavid M. Addict Behav. 2011 ; 36(8): 10.

[14]. Masson GS, Costa TS, Yshii L, Fernandes DC, Soares PP, et al. Time-Dependent Effects of Training on Cardiovascular Control in Spontaneously Hypertensive Rats: Role for Brain Oxidative Stress and Inflammation and BaroreflexSensitivity.PLoS One 2014; 9(5):e94927.

[15]. Wang X, Zhang M, Feng R, Li WB, Ren SQ, et al. Physical exercise training and neurovascular unit in ischemic stroke. Neuroscience 2014; pii: S0306-4522(14)00332-7.

[16]. Rolland, Y, Abellan VK, Vellas B. Physical Activity and Alzheimer's Disease: From Prevention to Therapeutic Perspectives. J Am Med Dir Assoc. 2008; 9:390-405.

[17]. Adlard PA, Perreau VM, Pop V, Cotman CW. Voluntary Exercise Decreases Amyloid Load in a Transgenic Model of Alzheimer's Disease. The Journal of Neuroscience. 2005; 25(17): 4217-4221.

[18]. Smith JC, Nielson KA, Woodard JL, Seidenberg M, Durgerian S, et al. Physical activity reduces hippocampal atrophy in elders at genetic risk for Alzheimer's disease.Front Aging Neurosciences. 2014; 6:61.

[19]. Pang, TY.,Stam NC, Nithianantharajah J, Howard ML, Hannan, AJ. Differential effects of voluntary physical exercise on behavioral and brain-derived neurotrophic factor expression deficits in Huntington's disease transgenic mice. Neuroscience. 2006; 141:569-584.

[20]. Nocera JR, Altman LJ, Sapienza C, Okun MS, Hass CJ. Can exercise improve language and cognition in Parkinson's disease? A case report. Neurocase: The Neural Basis of Cognition.2010; 16(4):301-306.

[21]. HS Yun, et al. Treadmill exercise ameliorates symptoms of attention deficit/hyperactivity disorder through reducing Purkinje cell loss and astrocytic reaction in spontaneous hypertensive rats. J ExercRehabil. 2014; 10 (1): 22-30.

[22]. Seo TB, Cho HS, Shin MS, Kim CJ, Ji ES, et al. Treadmill exercise improves behavioral outcomes and spatial learning memory through up-regulation of reelinsignaling pathway in autistic rats. Journal of Exercise Rehabilitation. 2013; 9(2):220-229.

[23]. Park JK, Lee SJ, Kim TW. Treadmill exercise enhances NMDA receptor expression in schizophrenia mice. Journal of Exercise Rehabilitation. 2014; 28:10 (1):15-21.

[24]. Colcombe SJ, Kramer AF, Erickson KI, Scalf P, McAuley E, et al. Cardiovascular fitness, cortical plasticity, and aging. Proceedings of the National Academy of Sciences USA. 2004; 101(9):3316-21.

[25]. Mark P. Mattson, WenzhenDuan, Ruqian Wan, and ZhihongGuo. Prophylactic Activation of Neuroprotective Stress Response Pathways by Dietary and Behavioral Manipulations. NeuroRx Journal. 2004; 1(1): 111-116.

[26]. Chodzko-Zajko WJ, Moore KA. Physical fitness and cognitive functioning in aging. Exercise Sport Sciences Reviews, ACSM. 1994; Vol. 22: p.195-220.

[27]. Colcombe SJ, Kramer AF, Erickson KI, Scalf P, McAuley E, et al. Cardiovascular fitness, cortical plasticity, and aging. Proceedings of the National Academy of Sciences USA. 2004; 101(9):3316-21.

[28]. Pietrelli A1, Lopez-Costa J, Goñi R, Brusco A, Basso N. Aerobic exercise prevents age-dependent cognitive decline and reduces anxiety-related behaviors in middle-aged and old rats. Neuroscience. 2012; 202:252-66.

[29]. Aguiar AS Jr, Castro AA, Moreira EL, Glaser V, Santos AR, et al. Short bouts of mild-intensity physical exercise improve spatial learning and memory in aging rats: involvement of hippocampal plasticity via AKT, CREB and BDNF signaling. Mech Ageing Dev. 2011; 132(11-12):560-7.

[30]. Ahlskog JE, Geda YE, Graff-Radford NR, Petersen RC. Physical exercise as a preventive or disease-modifying treatment of dementia and brain aging. Mayo Clin Proc. 2011 ; 86(9):876-84.

[31]. Sibley BA ,Etnier J L. The Relationship Between Physical Activity and Cognition in Children: A Meta-Analysis. Pediatric Exercise Science 2003; 15(3):243-256.