IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 10, October 2022

A Review on Effects of Physical Exercise on Cognitive Functioning and Wellbeing

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ABSTRACT: Many studies indicate that physical activity (PE) is a powerful gene modulator that causes anatomical and functional changes in the brain, resulting in significant improvements in cognitive performance and well-being. PE has also been shown to protect against neurodegeneration. However, it is unclear whether this protection is provided by changes to the molecular processes that underpin neurodegeneration or by improved resistance to assaults. This concise review examines the biological and psychological benefits of physical activity, describing findings from animal and human studies on brain plasticity and epigenetic mechanisms in order to better understand how to maximize the benefits of physical activity while avoiding negative consequences, such as exercise addiction.

KEYWORDS: Brain, Cognition, Epigenetic Mechanisms, Physical Exercise, Wellbeing.

1. INTRODUCTION

Many studies have shown that physical activity (PE) affects brain plasticity, which affects cognition and well-being. PE, according to experimental and clinical studies, causes structural and functional changes in the brain, resulting in significant biological and psychological benefits. When reporting PE effects, it is common practice to separate the biological from the psychological aspects. In fact, the majority of studies focused on the effects of PE on the brain (and subsequent cognitive functioning) or on overall well-being (in terms of physical and mental health). We'll combine both of these aspects in this review because they have an impact on each other. In fact, effective cognitive functioning is required for behaviorally appropriate choices [1]–[4].

Emotional emotions also have an impact on cognitive processes through unique brain circuits including prefrontal and limbic regions. Before we can look at the advantages of PE, we must first define it. Indeed, PE is frequently confused with physical activity (PA), which is defined as "any bodily movement produced by skeletal muscles that requires energy expenditure." Then, PA refers to any motor behavior, such as daily and leisure activities, and it is regarded as a lifestyle determinant for overall health. PE, on the other hand, is “a subcategory of physical activity that is planned, structured, repetitive, and has as a final or intermediate goal the improvement or maintenance of one or more components of physical fitness.” Aerobic and anaerobic activity, which are characterized by a precise frequency, duration, and intensity, are examples of PE.

We present data from both animal and human studies to demonstrate the biological and psychological benefits of PE on cognition and wellbeing in health and disease. The biological basis has been extensively researched at both the molecular and supramolecular levels. The current study also aims to present current evidence on epigenetic mechanisms that determine or modulate the biological effects of PE on the brain. In fact, while biologic mechanisms are well understood at the molecular and supramolecular levels, epigenetic mechanisms are poorly understood. Finally, the mode of PE that should be used to achieve these benefits while avoiding negative consequences will be discussed [5], [6].

1.1. Physical activity, cognition, and the brain:

The biological effects of PE linked to "neuroplasticity" are particularly significant. The nervous system's ability to modify itself in response to experience is known as neuroplasticity. As a result, PE could be considered an environmental factor that promotes neuroplasticity. The structural changes studied in animal studies are at the cellular (neurogenesis, gliogenesis, synaptogenesis, and angiogenesis) and molecular (alteration in neurotransmission systems and increase in some neurotrophic factors) levels, whereas functional activity has been measured using levels of performance in behavioral tasks, such as spatial tasks that allow for the analysis of various face features. In humans, indicators of structural changes include brain volumes, white matter integrity measurements, and neurotrophin levels modulation (by correlation with trophic factors plasma levels). These metrics can be linked to cognitive abilities, resulting in the definition of functional neural efficiency. In this regard, it is important to note that any morphological change affects the functional properties of a neural circuit, and vice versa, any change in neuronal efficiency and functionality is due to morphological changes.

1.2. Animal Research:

Instead of PE, motor activity or motor exercise are frequently used in animals. In rodents, the effects of motor exercise are mostly studied through specific wheel training or locomotor activity analyses. Excessive motor activity increases the proliferation rates of neurons and glia cells in the hippocampus and neocortex, as well as induces angiogenesis in the neocortex, hippocampus, and cerebellum, according to studies on healthy animals. Motor activity causes changes in neurotransmitters like serotonin, noradrenalin, and acetylcholine, as well as the release of brain-derived neurotrophic factor and insulin-like growth factor at the molecular level. Motor exercise improved spatial abilities as well as other cognitive domains such as executive functions in animals, demonstrating that motor exercise improves cognitive functions.

Even in older animals and animal models of neurodegenerative diseases, similar structural and functional changes were observed, suggesting that motor exercise is a powerful neuroprotective factor against physiological and pathological aging. In this case, transgenic models can be used to determine when a structural change occurs and then to investigate when the animals should be given motor training to maximize the effects. In this regard, accumulating evidence suggests that motor activity should be performed prior to the onset of neurodegeneration in order to benefit from its protective effects, such as before the formation of beta amyloid plaques in Alzheimer's disease. However, some experimental evidence suggests that motor exercise performed after neurodegenerative lesions improves spatial abilities, making it a potentially effective therapeutic agent [7]–[10].

PE, interestingly, causes changes in the offspring that can be passed down. Positive maternal experiences, in fact, can have a behavioral and biochemical impact on the offspring. Preclinical research has also shown that the effects of maternal exercise during pregnancy can be passed down to the children. However, it is unclear whether inheritance possibilities are limited to motor exercise alone. In this regard, pregnant rats exposed to motor exercise such as wheel-running and treadmill running produce offspring with improved spatial memory and higher hippocampal BDNF levels. However, more research is needed to determine whether these beneficial effects are the result of physiological changes in the in utero environment or epigenetic changes in the developing embryo. On the other hand, few studies, which are contradictory and difficult to replicate, do not yet allow for the investigation of paternal motor exercise's transgenerational effects.

1.3. Human Research:

Even in humans, neuroplasticity has been observed following PE. PE causes structural changes in adults, such as increased gray matter volume in the frontal and hippocampal regions and reduced gray matter damage, according to numerous studies.

PE also increases blood flow, improves cerebrovascular health, and determines benefits on glucose and lipid metabolism, which transports "food" to the brain. These impacts are mirrored in cognitive performance. In fact, cross-sectional and epidemiological studies have shown that PE improves cognitive functions in both young and older adults, including memory, attentional efficiency, and executive-control processes. Furthermore, in comparison to sedentary individuals, structural changes following PE have been linked to academic achievement. In this vein, it was also discovered that children who engaged in regular aerobic activity performed better on verbal, perceptual, and arithmetic tests than sedentary children of the same age.

PE has been shown in numerous studies to prevent cognitive decline associated with aging, reduce the risk of dementia, improve executive function, and improve overall quality of life. PE also determines changes in metabolic networks linked to cognition, according to studies based on positron emission tomography.

PE influences network topology, according to recent studies on magnetoencephalography-based (MEG) functional connectivity. It's important to remember that, in comparison to fRMI, MEG is a much more direct measure of neural activity, with the added benefit of combining good spatial and temporal resolution. PE was linked to better inter-modular integration and improved cognitive functions in healthy people. PE has been shown to have benefits in people who are at risk for Alzheimer's disease, implying that it may play a protective role.

PE may stimulate blood circulation in the neural circuits involved in cognitive function, which could explain these beneficial structural and functional effects. Another explanation may be found in the notion of "cerebral reserves," a process that could explain why, despite comparable neurodegenerative alterations in form and degree, individuals' cognitive aging and clinical dementia severity varies greatly. There are two types of reserves: brain reserve and cognitive reserve. The former is based on the protective potential of anatomical features like brain size, neuronal density, and synaptic connectivity, while the latter is based on efficient neural circuit connectivity.

1.3. Anxiety and Depression:

Depression is the most prevalent mental disorder, and by 2020, it will be the second greatest cause of death. Anxiety disorders, which are among the most common mental illnesses in the global population, are a same entity. PE has repeatedly been shown to reduce sadness and anxiety in epidemiological research. Individuals who participate in PE on a regular basis, for example, are less sad or nervous than those who do not, suggesting that exercise may be used to cure these diseases.

The majority of research on the relationship between PE and positive mood changes has found positive effects, particularly as a result of aerobic exercise, regardless of the specific type of activity, even if the optimal intensity of aerobic PE to control and reduce symptoms is still debated. Individuals with major depressive disorder (MDD) were found to have significantly reduced depressive symptoms after about 16 weeks of an aerobic exercise program. However, there is evidence that even anaerobic activity has beneficial effects in the treatment of clinical depression. It has been proven that the positive effects of PE can be seen even with short bursts of exercise for anxiety disorders, regardless of the nature of the exercise.

Modulation of peripheral BDNF levels was found to be a physiologic mechanism linked to the improvement in depressed mood after PE. In this vein, it was recently proposed that the intensity of exercise prescribed to improve mood be determined on an individual basis rather than based on the patient's preferred intensity. Physical inactivity, on the other hand, was linked to worsening depressive symptoms and, as a result, lower BDNF levels in the peripheral blood. Lower oxidative stress may also contribute to improved mood after PE. It was demonstrated in this competition that people with MDD or bipolar disorder have abnormal oxidative stress, and that PE, especially at higher intensities, reduces oxidative stress and improves mood.

1.4. Addictive and Unhealthy Behaviors:

PE has been shown to be an effective treatment for a variety of addictive and unhealthy behaviors. PE has been shown to decrease and prevent habits like smoking, drinking, and gambling, as well as control appetite and satiety. Several studies have shown that substance abusers benefit from regular physical activity, which also helps to increase healthy behaviors. Regular physical activity has been shown to reduce tobacco cravings and cigarette use. Although PE has positive effects on psychological well-being, it is important to note that it can also reveal unhealthy behaviors that are harmful to one's health. It is the case of exercise addiction, a dependence on a regular exercise regimen characterized by withdrawal symptoms such as anxiety, irritability, guilt, muscle twitching, a bloated feeling, and nervousness after 24–36 hours without exercise. There is a significant link between exercise addiction and eating disorders, suggesting that both illnesses are comorbid and share a biological substrate. Recent research has found that these unhealthy behaviors are linked to decreased prefrontal cortex volume, activity, and oxygenation, as well as impairments in cognitive functions such as inhibitory control and compulsive behaviors. PE has also been shown to improve mental health by increasing oxygenation of the prefrontal cortex over a few days.

1.5. Epigenetic Mechanisms:

PE's biological and psychological effects may be explained in part by epigenetic mechanisms. The term "epigenetics" refers to a conceptual model that explains how genes interact with their surroundings to produce phenotypes. Epigenetics refers to all mechanisms that regulate gene expression by modeling chromatin structure while keeping the nucleotide sequence of DNA unchanged, such as DNA methylation, post-translational histone modifications (i.e., acetylation and methylation), and microRNA expression.

The current literature clearly demonstrates that different biological and environmental factors, such as PE, have a strong influence on these mechanisms, determining the nature and mode of epigenetic mechanism activation. In neural reorganization, epigenetics, including those that govern brain plasticity, plays a critical role. A growing body of evidence suggests that regulates neuroplasticity and memory processes, for example.

Several animal studies show that motor activity can improve cognitive performance by influencing the expression of genes involved in neuroplasticity via epigenetic mechanisms. DNA methylation, histone modifications, and microRNA expression are the three main molecular processes that underpin epigenetic mechanisms. DNA methylation is a chemical modification of the double-stranded DNA molecule's cytosine. DNA methylation has long been known to play a role in long-term memory. Memory-suppressor genes are relieved of their repressive effects by mechanisms related to DNA methylation, which favors the expression of plasticity-promoting and memory consolidation genes. PE is able to coordinate the activity of genes involved in synaptic plasticity that control memory consolidation, according to many evidences.

Histone modifications are chemical changes made to histone proteins after they have been translated. Histone methylation/demethylation, acetylation/deacetylation, and phosphorylation are all caused by the activity of specific enzymes that change the chromatin structure and thus regulate gene expression. Histone acetylation has been shown to be a requirement for long-term memory (LTM). Motor activity improves memory performance in behavioral tasks in animals by increasing these genetic mechanisms in the hippocampus and frontal cortex. Recently, it was discovered that after 4 weeks of motor exercise, the activity of enzymes involved in histone acetylation/deacetylation, the epigenetic mechanisms that determine an increase in BDNF expression, increased.

MicroRNAs (miRNAs) are single-stranded RNA molecules that can prevent target genes from being expressed. They are widely expressed in the brain, where they play a role in epigenetic mechanisms and regulate a variety of biological processes such as cell proliferation, differentiation, apoptosis, synaptic plasticity, and memory consolidation. PE has been shown to reduce the negative effects of traumatic brain injury and aging on cognitive performance via modulating the expression of miR21 and miR34a in the hippocampus nucleus. PE also helps to reduce the effects of stress-induced increases in miR-124, which is involved in neurogenesis and memory formation.

2. DISCUSSION

According to sport psychology, the success or failure of PE programs is determined by many variables, including the intensity, frequency, and length of the exercise, as well as whether the activity is done in a group or alone. These factors are essential for maintaining PE practice and gaining advantages for the brain and behavior, and they are influenced by individual differences. Although such factors must be considered when training is suggested, scientific studies have shown that whether PE is done in an aerobic or anaerobic mode has distinct impacts on cognitive functioning and health.

Aerobic exercise adjusts the intensity (from low to high), duration (typically lengthy), and oxygen availability to allow for the resynthesis of adenosine triphosphate (ATP) via aerobic processes. The intensity is determined by the cardiorespiratory effort in relation to the maximum heart rate (HRmax) or maximum oxygen consumption (Vo2max), which indicates an increase in oxygen consumption over rest. Jogging, running, cycling, and swimming are all examples of aerobic PE.

Anaerobic exercise, on the other hand, has a high intensity, a short duration, and little oxygen availability, resulting in a depletion of the muscles' ATP and/or phosphocreatine (PCr) stores and a change in ATP synthesis to anaerobic energy processes, lactacid or alactacid. Weight lifting and sprinting in the 100 meter are two examples of anaerobic workouts. Chronic aerobic exercise has been linked to significant structural and functional neuroplastic changes, as well as improved cognitive skills and a greater sense of well-being, according to a large body of evidence.

  UGC CARE Listed (Group -I) Journal Volume 11, Iss 10, October 2022

A increasing body of data suggests that acute aerobic exercise, defined as a single bout of physical activity, is linked to enhanced cognitive functioning, particularly prefrontal cortex-dependent cognition. The benefits of a single session of exercise on cognitive performance, on the other hand, are usually minor. In this vein, even a single session of moderate-intensity aerobic exercise has been shown to improve mood, emotional states, and overall wellness in MDD patients.

3. CONCLUSION

PE has beneficial biological and psychological benefits on the brain and cognitive performance, as well as promoting a feeling of well-being. PE is essential in preventing both normal and pathological aging. PE has been found to cause powerful neuroplastic changes, which are mediated in part by epigenetic pathways. PE, in reality, causes significant changes in gene expression and protein products, which are manifested as epigenomic manifestations. An increasing amount of evidence suggests that both chronic and aerobic physical activity may provide comparable advantages. These findings should prompt people to consider the positive benefits of physical activity and to advocate its usage as a modifiable factor in disease prevention, cognitive enhancement, and mood enhancement. Despite all of these benefits, it is important to note that PE should be customized to the individual. In fact, when physical activity becomes obsessive and promotes addictive behaviors, it may have a negative side.

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