



Examining the Effects of Exercise on Neuroplasticity and Depression Disorder: Implications for Depression Treatment

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ABSTRACT

Depression is a serious public health issue with a high risk of mortality and limited access to pharmacological and psychotherapeutic treatments. Exercise serves as an effective and readily accessible alternative intervention in addressing depression by influencing brain neuroplasticity and various aspects of mental health. This article is an integrative review that analyzes the potential of brain neuroplasticity in reducing depression symptoms through exercise, exploring literature related to depression, exercise, and neuroplasticity to generate implications for depression management. The article was retrieved via Google Scholar, and a synthesis of 38 relevant articles was conducted. The results indicate that depression affects brain structure and function, which are also associated with neuroplasticity. Exercise has the potential to stimulate brain neuroplasticity, particularly in areas affected by depression, such as the hippocampus and prefrontal cortex. This potential makes exercise an effective yet cost-effective and easily accessible alternative for the prevention and treatment of depression, especially mild to moderate depression.

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INTRODUCTION

Depression is a public health problem that has a significant impact on physical and mental health. This disease has a high recurrence rate and is closely associated with a high mortality rate, which is often related to suicide and the presence of comorbid diseases, such as cardiovascular disease.(Rajan et al., 2020). According to the World Health Organization (WHO), depression is expected to be the main cause of death by 2030. (Lepine & Briley, 2011)

Depression is a mental disorder that can be treated through pharmacological and non-pharmacological interventions, such as psychotherapy. However, the effectiveness of

pharmacological treatment is limited, and antidepressant use is often associated with side effects and low compliance rates. Antidepressant use also carries a high risk of cardiovascular disease, sexual dysfunction, weight gain, digestive disorders, dry mouth, and even suicidal thoughts. (Y. B. Wang et al., 2023). Aside from side effects, another challenge in pharmacotherapy treatment is that 10-30% of depression survivors show treatment-resistant symptoms, with difficulties in social functioning, decreased physical health, and thoughts of suicide. (Al-Harbi, 2012). According to the 2018 Riskesdas Report, only 9% of depression survivors in Indonesia received treatment. (Kemenkes RI, 2019). Antidepressant drugs can only be obtained with a prescription from a psychiatrist, and the problem is that public access to psychiatrists is hampered due to the uneven distribution of health facilities that provide this service. Other barriers include high costs of depression care and low societal incomes, reflecting inequalities in access to treatment for depressed patients. Distribution of antidepressant drugs to remote areas also often causes depressed patients in Indonesia to experience drug withdrawal, increasing the risk of relapse. This becomes a big issue if Indonesia relies too much on pharmacotherapy treatment to treat depression. In addition to pharmacological interventions, psychotherapy such as cognitive behavioral therapy (CBT), psychodynamic therapy, problem-solving therapy, interpersonal therapy (IPT), and social skills training are also a common choice for depressed patients. Unfortunately, psychotherapy is expensive, takes a long time, and requires highly trained professionals. (Ross et al., 2023)

In Indonesia, with a population of almost 270 million people, the number of professionals trained to provide psychotherapy is very limited, with only 3924 clinical psychologists. (Ikatan Psikolog Indonesia, 2023). The emergence of various challenges related to side effects and limited access to pharmacotherapy and psychotherapy interventions has encouraged research to test alternative depression treatment programs that are effective, easy to implement, accessible, and affordable.

One interesting alternative is sport. Based on empirical evidence, research shows that exercise has the advantages of having no dangerous side effects, affordable costs, widespread access, and many additional benefits. Apart from having a direct impact on depression, exercise can also help overcome comorbid diseases, improve quality of life, and support mental health.

Sport refers to body movements carried out in a planned, structured, and repetitive manner to improve or maintain components of physical fitness. (Stennett et al., 2020). The positive relationship between exercise and depression has been confirmed by several studies. The research results show that physical activity is effective in reducing levels of depression in individuals. (Recchia et al., 2022)

People who exercise regularly tend to experience improved mental health which is reflected in reduced symptoms of depression. (Pickersgill et al., 2022). The mechanism behind the reduction in depressive symptoms due to exercise activity can be explained by various biomarkers in the brain. One brain mechanism that may explain the positive effects of exercise on depressive symptoms is neuroplasticity.

Neuroplasticity refers to the ability of the brain to undergo functional and structural changes in response to external or internal stimuli, such as the environment or internal processes in the body. (Voss et al., 2017). Several meta-analyses have revealed that depression is associated with structural abnormalities in the brain, including decreased volume of the hippocampal, prefrontal, orbitofrontal, and anterior cingulate cortices.



In addition, depression is also associated with changes in blood flow in various brain regions, as well as impaired cellular and molecular mechanisms of neuroplasticity. (Ross et al., 2023)

Stimulating the molecular and cellular mechanisms of neuroplasticity may help overcome some of these structural abnormalities and improve brain function in areas associated with depressive symptoms. (Kandola et al., 2019). Therefore, targeting these neuroplasticity mechanisms emerges as an attractive treatment approach. (Duman & Pittenger, 2008)

This article will review the potential of exercise as an adjunct intervention in the treatment of depression and its effects on reducing other mental disorders contributing to improved overall mental health. As previously explained, exercise has a positive impact on brain mechanisms, including hormone release, increased hippocampal volume, and brain neuroplasticity effects. Although previous studies have widely reported the influence of exercise on hormone release, increased hippocampal volume, and other mechanisms, the relationship between exercise, brain neuroplasticity, and reduced depressive symptoms remains a limited area of research. Therefore, this article aims to explain the potential of exercise to influence brain neuroplasticity and its impact on reducing depressive symptoms.

METHOD

This article was written using a literature review approach. The American Psychological Association (2020) explains that literature reviews aim to make conclusions and evaluations on a particular topic. (American Psychological Association, 2020) This research article consists of an introduction, research methods, discussion, implications, and conclusions. The discussion in this article aims to explore the potential of brain neuroplasticity to reduce depressive symptoms through exercise.

To achieve the objectives of this research, the author conducted an integrative review (Torraco, 2005) to analyze certain concepts and topics used in the research, such as depression, exercise, and neuroplasticity potential.

As the primary goal of the integrative review, the authors synthesize emerging concepts and topics to generate new viewpoints and propose implications for efforts to treat depressive disorders. The literature review was not carried out systematically, because the literature review used in this research was a narrative review which is a traditional form of literature review method. In a traditional literature review, researchers collect and synthesize literature to show the value of a particular point of view, and it is not done systematically.

All literature supporting this review was explored simultaneously in Google Scholar, using keywords such as “**depression and neuroplasticity**”, “**exercise and depression**”, and “**exercise and neuroplasticity**”. The author then carried out a synthesis of 38 articles found to be relevant. The synthesis mechanism is carried out through three stages: depression and exercise from the point of view of neuroplasticity; the effect of exercise on reducing depressive symptoms through neuroplasticity mechanisms; as well as conclusions and implications that can be applied as part of Indonesia's efforts to treat depressive disorders.

RESULT

Depression and Neuroplasticity

The American Psychiatric Association (2013) defines depression as a mood disorder characterized by symptoms such as prolonged feelings of sadness, loss of interest or pleasure in previously enjoyed activities, weight changes, sleep disturbances, chronic fatigue, feelings of low self-esteem, and difficulty concentrating. , and thoughts related to death or suicide. Depression survivors experience various behavioral changes and biological changes in the brain. These structural changes in the brain relate to specific parts of the nervous system, including the frontal lobe, cingulate gyrus, striatum, white matter, and hippocampus. (Y. B. Wang et al., 2023)

Research by Akiyama et al. (2018) also revealed that the left frontal lobe in individuals with depression had low levels of blood oxygen metabolism, which is believed to be related to depressive symptoms. Not only that, depression also has an impact on neuroplasticity. Neuroplasticity refers to the ability of the brain to change the structure and reorganize synaptic connections, including the formation and withdrawal of synapses, spinogenesis, synaptogenesis, axon growth and regeneration, and the growth and formation of dendrites.

Exercise and Neuroplasticity.

The human brain can adapt to changing demands by changing its functional and structural properties—a process known as neuroplasticity—which contributes to learning and skill development. Neuroplasticity can occur in response to a variety of factors, including new learning, nervous system damage, and sensory deficits. (Bavelier & Neville, 2002)

Sport is a type of physical activity that is carried out repeatedly to improve or maintain physical fitness.(Recchia et al., 2022) and sport has been shown to have a positive relationship with neuroplasticity. (Fernandes & Ortonio. tgrayrine Figuera, 2020)

Depression and Exercise: Effects of Neuroplasticity.

Various studies have shown that depression can affect neuroplasticity, and therefore, neuroplasticity is considered key in the treatment of depression. (Akyuz Ozdemir & Can, 2021) Previous research shows that exercise has the potential to stimulate neuroplasticity (Pickersgill et al., 2022) and may be a potential alternative in treating depression. Exercise stimulates neuroplasticity in various parts of the brain that are negatively affected in individuals with depression, such as the hippocampus, prefrontal cortex, and anterior cingulate cortex (Gujral et al., 2017) Therefore, exercise done regularly has been shown to have a positive impact on neuroplasticity, which in turn is beneficial for reducing depression. Changes in neuroplasticity may also be one of the main reasons for depression (Zhao et al., 2020).

Implications for Treating Depression in Indonesia

The high prevalence of depression is experienced by 6.1% of the adult population in Indonesia. (Kemenkes RI, 2022) as well as the difficulty of access and lack of government support (Putri et al., 2021) means that sport can be an alternative prevention and treatment for depressive disorders, especially mild to moderate depression (Carek et al., 2011) Apart from its positive effects on brain neuroplasticity, exercise is also a treatment that has low costs and easy access (Busch et al., 2016) Therefore, its implementation in Indonesia is very possible.



DISCUSSION

Depression and Neuroplasticity

Depression is a mood disorder characterized by symptoms such as prolonged feelings of sadness, loss of interest or pleasure in previously enjoyed activities, weight changes, sleep disturbances, chronic fatigue, feelings of low self-esteem, difficulty concentrating, and thoughts of death or suicide. Self Changes in the brain of depressed patients not only affect the structure but also the function of the brain. Brain dysfunction in depressed patients is reflected in changes in neurological activity when they undergo cognitive tasks. (Zhao et al., 2020). Research by (Akiyama et al., 2018) also revealed that the left frontal lobe in individuals with depression had low levels of blood oxygen metabolism, which is believed to be related to depressive symptoms.

Not only that, depression also has an impact on neuroplasticity. Neuroplasticity refers to the brain's ability to change the structure and reorganize synaptic connections, including synapse formation and withdrawal, spinogenesis, synaptogenesis, axon growth and regeneration, and dendrite growth and formation (Albert, 2019). Exciting research has identified 8 neural biotypes associated with various depressive symptoms, such as complication, anxious avoidance, negativity bias, threat dysregulation, anhedonia, context insensitivity, ignorance, and cognitive dyscontrol.

Analysis of the neural circuits underlying each of these biotypes can guide clinical treatment strategies and predict response to treatment. For example, anhedonia, which is associated with the hypoactivation of striatal pathways, may respond well to drugs that affect neuroplasticity in striatal dopaminergic circuits, such as pramipexole.

Chronic stress and depression can also cause significant changes in the brain, including a decrease in the number of dendrites and synapses, atrophy of dendrites, and a decrease in the size and number of glial cells in the hippocampus and prefrontal cortex. (Serafini, 2012)

Therefore, in a context where organic changes can influence both cognitive and behavioral levels, the neuroplasticity capacity of the brain remains an important consideration. Thus, in the case of major depression, the neuroplasticity capacity of the brain is affected, affecting the hippocampus (which is involved in learning and memory), the prefrontal cortex (which plays a role in attention, concentration, learning, and memory), and the amygdala (which plays a role in emotional processing and social learning) (McEwen et al., 2016).

Some types of antidepressants help improve neuroplasticity mechanisms by repairing damage to neural circuits, strengthening synapses in certain brain areas, or normalizing glutamate levels (Rădulescu et al., 2021). Likewise, psychotherapy, through its various processes, can influence changes in the brain, increase neuroplasticity, and improve brain function in patients with mental health disorders (Malhotra & Sahoo, 2017). In addition to antidepressants and psychotherapy, exercise also has a positive impact on brain neuroplasticity.

Exercise and Neuroplasticity

The human brain can adapt to changing demands by changing its functional and structural properties—a process known as neuroplasticity—which contributes to learning and skill development. Neuroplasticity can occur in response to a variety of factors, including new learning, nervous system damage, and sensory deficits (Bavelier & Neville, 2002). The degree of neuroplasticity that occurs as a result of experience or learning can be influenced by various factors that influence brain activity. One important factor in maintaining mental health and influencing brain structure and function is exercise.

The types of exercise used in research varied, including aerobic exercise, cycling, tai chi, qigong, swimming, dancing, yoga, resistance training, and weight lifting ((Pickersgill et al., 2022). However, aerobic exercise is the most common type of exercise used in research (Wegner et al., 2020). Regular aerobic exercise can reduce depressive symptoms in patients with chronic inflammatory diseases(Perna et al., 2010)

Exercise influences neuroplasticity by triggering molecular and cellular changes that influence cognitive function and behavior. Brain neuroplasticity involves the regulatory processes of neurogenesis, synaptogenesis, gliogenesis, and angiogenesis (Stillman et al., 2016) These processes are important for nerve growth and synapse formation because an adequate blood supply is essential to provide the nutrients needed to support brain neural development (Xiong et al., 2010) In this way, exercise contributes to improved cognitive and motor function which in turn influences behavior (El-Sayes et al., 2019).

Even light exercise, such as running in the morning, can help reduce symptoms of depression. This running therapy is recommended by the American College of Sports Medicine (Department of Health and Human Services, 2018) and has been proven to be successful in reducing depression and anxiety. (Carek et al., 2011) Neuroplasticity enables adaptation to changing demands and environments. The question that arises is how to enhance neuroplasticity mechanisms to improve learning, and memory, prevent cognitive decline across the lifespan, and support recovery after brain injury. Evidence from human and animal studies suggests that physical activity and exercise have a supportive effect on neuroplasticity and are often associated with improved cognitive function. With increased neuroplasticity, physical exercise can also facilitate more effective learning, while also facilitating maladaptive learning, such as the acquisition of fears or undesirable habits (Hotting & Roder, 2013).

Human studies show that physical activity facilitates neuroplasticity in various areas of the brain, including increased white matter and gray matter. (Fernandes & Ortonio. tgrayrine Figuera, 2020)

Therefore, it can be concluded that exercise, especially aerobic exercise, is an effective method for improving brain neuroplasticity. Through these neuroplasticity mechanisms, exercise allows the brain to change structure and reorganize synaptic connections, which in turn can influence cognitive function and behavior (El-Sayes et al., 2019).

The mechanism by which exercise helps in overcoming depression through neuroplasticity can be explained in several ways. Exercise stimulates neuroplasticity in various parts of the brain that are negatively affected in individuals with depression, such as the hippocampus, prefrontal cortex, and anterior cingulate cortex.

Therefore, exercise done regularly has been shown to have a positive impact on neuroplasticity, which in turn is beneficial for reducing depression. Changes in neuroplasticity can also be one of the main reasons for depression. (Kandola et al., 2019)



Depression and Exercise: Effects of Neuroplasticity

Various studies have shown that depression can affect neuroplasticity, and therefore, neuroplasticity is considered key in the treatment of depression. (S.-M. Wang et al., 2018) Apart from psychotherapy and pharmacotherapy. (Malhotra & Sahoo, 2017; Rădulescu et al., 2021) studies show that exercise has the potential to stimulate neuroplasticity (Pickersgill et al., 2022)) and may be a potential alternative in treating depression.

Exercise stimulates neuroplasticity in various parts of the brain that are negatively affected in individuals with depression, such as the hippocampus, prefrontal cortex, and anterior cingulate cortex. (Gujral et al., 2017)

Research by Gorham et al. in 4,191 children aged 9-11 years showed that hippocampal volume acts as a mediator between exercise and depressive symptoms, suggesting that exercise can increase hippocampal volume in individuals with depression (Gorham et al., 2019) Therefore, neuroplasticity is an important pathway through which exercise exerts its antidepressant effects (Kandola et al., 2019)

In addition, exercise can also promote neuroplasticity and overcome depression through the brain-gut axis (Dalton et al., 2019). The brain-gut axis is a bidirectional response system between the brain and intestines mediated by neuroendocrine pathways (Chakrabarti et al., 2022). Abnormal expression of gut-brain peptides in the central and peripheral nervous systems can lead to depression, anxiety, digestive disorders, and metabolic disorders. Exercise can ameliorate the abnormal expression of peripheral or central brain-gut peptides (ghrelin, NPY, CCK, PYY, and GRP), and thereby influence monoamine neurotransmitter levels, spinal cord HPA activity, neurotrophic factor expression, neuroplasticity, cell apoptosis, metabolism of neurotoxic substances, and epigenetics, ultimately resulting in antidepressant effects. (Bosi et al., 2020)

The process of exercise's influence on depression management can be explained through short-term processes and long-term processes. In the short term, endorphins and dopamine help improve mood and deal with stress. In the long term, the release of neurotransmitters in response to exercise drives changes in the brain that help mood and cognition, reduce inflammation, and improve immune function, all of which affect brain function and mental health. (Portugal et al., 2013)

In individuals with depression, exercise has three main effects on neuroplasticity. First, exercise helps rebuild brain structure. Second, exercise activates the functions of various parts of the brain associated with depression. Third, sport encourages adaptive behavioral changes. In addition, exercise also contributes to maintaining hippocampal volume and gray matter volume integrity, which in turn increases the efficiency of the brain's neural processing and slows the decline in cognitive function.

Exercise aids in depression recovery through positive modulation of Brain-Derived Neurotrophic Factor (BDNF), a protein that promotes neuroplasticity.

Research by Jemni et al. (2023) also showed that exercise can increase BDNF levels and improve neuroplasticity, which in turn can lead to improvements in mood and cognitive function. Thus, exercise has an important role in improving neuroplasticity in individuals with depression, and its effects help overcome the clinical symptoms of depression by restoring reduced neuroplasticity. (Bruchle et al., 2021)

In the end, exercise has been proven to have a positive impact on depression sufferers. Recent research by (Jagmohan Singh., 2012) shows that exercise is an effective way to deal with mental health problems, and can even be more effective than medication or counseling. Immediately after exercise, endorphins and dopamine are released in the brain. Regular exercise can improve sleep quality, which plays an important role in the management of depressive symptoms. (Dolezal et al., 2017)

Implications for Treating Depression in Indonesia

The high prevalence of depression is experienced by 6.1% of the adult population in Indonesia. (Kemenkes RI, 2022) as well as the difficulty of access and lack of government support (Putri et al., 2021) means that sports can be an alternative prevention and treatment for depressive disorders, especially mild to moderate depression (Carek et al., 2011) Some of the sports recommended for treating depression include cardio exercise, such as walking, running, aerobics, cycling, etc. Apart from that, aquatic sports such as swimming also show positive results in treating depression. Yoga also shows the same results. However, sports that train endurance such as weight lifting have not been widely studied, even though they show positive results for young populations (Rogers, 2022) The recommended time estimate is 150 minutes per week. (Jagmohan Singh., 2012)

CONCLUSION

Depression affects brain structure and function, including neuroplasticity, which is crucial in the treatment of depression. However, commonly used psychotherapy and pharmacotherapy have several shortcomings regarding access and resources. Exercise is considered to be an alternative treatment for depression. Apart from affordable access, exercise is also able to stimulate neuroplasticity, which is also associated with depression. Through influences on structure, function, and neurotropism, exercise stimulates neuroplasticity and supports recovery from depression.

SUGGESTION

Future research evaluating the impact of a lack of government support on the prevention and treatment of depression is also important, to formulate policy recommendations that can improve access and support. Additionally, research into the effectiveness of exercise interventions, focusing on cardio, aquatic exercise, yoga, and resistance training, may provide insight into which types of exercise are most beneficial. The influence of exercise frequency and duration needs to be further explored. Finally, research on government and community involvement in supporting sports programs as a national strategy to overcome depression can provide important information for improving policy and social support.

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