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Effect of Exercise on Neurotransmitters: A Systematic Review

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ABSTRACT

Exercise has important regulatory effects on the central nervous system and positively affects cognitive functions, mental health and motivation by modulating neurotransmitter levels. This systematic review aimed to examine the effects of exercise on neurotransmitters. The compilation was conducted based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guide. As a result of a comprehensive literature review conducted according to the inclusion criteria determined in the research, a total of nine academic studies on the subject were evaluated. As a result of the evaluation, it was revealed that exercise directly affects brain metabolism and causes significant changes in the levels of neurotransmitters such as dopamine, serotonin, noradrenaline and GABA. It has also been determined that exercise supports neuroplasticity by increasing neurotrophic factors. In conclusion, existing literature findings show that exercise creates multifaceted effects on brain chemistry and has serious effects on neurotransmitters. Accordingly, a more in-depth investigation of the neurobiological foundations of exercise is of great importance in understanding how exercise-based interventions affect neurological disorders. In the light of this information, the effects of different types of exercise (endurance, resistance, high-intensity interval training, etc.) on neurotransmitter levels can be discussed comparatively.

Keywords: Exercise, Neurotransmitters, Gamma Aminobutyric acid

Egzersizin Nörotransmitterler Üzerindeki Etkisi: Sistematik Bir İnceleme

TURKISH SUMMARY

Egzersiz, merkezi sinir sistemi üzerinde önemli düzenleyici etkilere sahiptir ve nörotransmitter seviyelerini modüle ederek bilişsel işlevleri, ruh sağlığını ve motivasyonu olumlu yönde etkiler. Bu sistematik derleme, egzersizin nörotransmitterler üzerine etkilerini incelemeyi amaçlamıştır. Derleme, PRISMA (Sistematik İncelemeler ve Meta-Analizler için Tercih Edilen Raporlama Öğeleri) kılavuzuna dayalı olarak gerçekleştirilmiştir. Araştırmada belirlenen dahil etme kriterlerine göre yapılan kapsamlı bir literatür taraması sonucunda, konu ile ilgili toplam dokuz akademik çalışma değerlendirilmiştir. Değerlendirme sonucunda, egzersizin beyin metabolizmasını doğrudan etkilediği ve dopamin, serotonin, noradrenalin ve GABA gibi nörotransmitterlerin seviyelerinde önemli değişikliklere neden olduğu ortaya çıkmıştır. Ayrıca egzersizin nörotrofik faktörleri artırarak nöroplastisiteyi desteklediği belirlenmiştir. Sonuç olarak, mevcut literatür bulguları, egzersizin beyin kimyası üzerinde çok yönlü etkiler yarattığını ve nörotransmitterler üzerinde ciddi etkileri olduğunu göstermektedir. Buna göre, egzersize dayalı müdahalelerin nörolojik bozuklukları nasıl etkilediğini anlamak için egzersizin nörobiyolojik temellerinin daha derinlemesine incelenmesi büyük önem taşımaktadır. Bu bilgiler ışığında farklı egzersiz türlerinin (dayanıklılık, direnç, yüksek yoğunluklu interval antrenmanı vb.) nörotransmitter düzeyleri üzerindeki etkileri karşılaştırmalı olarak tartışılabilir.

Anahtar Kelimeler: Egzersiz, Nörotransmitterler, Gama Aminobütirik Asit

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INTRODUCTION/ INTRODUCTION

Exercise refers to the performance of planned, systematic and repetitive physical activities in order to optimize an individual's physical health, endurance, strength and general fitness. (American College of Sports Medicine, 2018). According to current definitions, exercise is a multidimensional phenomenon that aims to support not only physical health but also mental and psychosocial well-being. (Craft and Perna, 2004)

While regular exercise improves mobility by increasing the endurance of the musculoskeletal system, it also has positive effects on the cardiovascular system. It has been widely documented in the literature that exercise is not only limited to physical parameters, but also makes significant contributions to mental and psychological well-being. (Salmon, 2001) Studies reveal that regular exercise provides various psychological benefits such as stress management, mood regulation and improvement of cognitive functions (Gökçe et al., 2019). In this context, it can be said that considering exercise within the framework of a bio-psychosocial model is of critical importance for the holistic health of the individual.

The effects of exercise on psychological and physiological well-being occur largely through its interactions with the central nervous system and neurochemical mechanisms. Neurotransmitters, as chemical compounds that enable communication between nerve cells, have a decisive role in the psychological state, motivation, learning capacity and emotional reactions of the individual. Exercise can increase the psychological and physiological well-being of individuals by modulating the release and receptor sensitivity of neurotransmitters, especially dopamine, serotonin, gamma-aminobutyric acid (GABA) and norepinephrine (Şahin, 2005).

Various studies have shown that different exercise types and intensities have unique effects on neurotransmitter levels. (Lin and Kuo, 2013). Aerobic exercises can relieve symptoms of stress and depression by increasing serotonin and norepinephrine levels. For example, regular endurance training balances mood by increasing serotonin release (Gökçe et al., 2019). In addition, anaerobic exercises such as high-intensity interval training (HIIT) improve attention, motivation and cognitive performance by increasing dopamine and norepinephrine levels (Heisz et al., 2017). Strength training can support the inhibitory mechanisms of the nervous system by increasing GABA activity. GABA is one of the most important inhibitory neurotransmitters of the central nervous system and plays a critical role in reducing anxiety, promoting relaxation, and managing stress (Luscher, Shen, and Sahir,

2011). Increasing GABA levels during and after exercise increases the feeling of calm and balance in individuals (Şahin, 2005).

In this context, it has been shown that regular exercise positively affects neurotransmitter levels in the brain and enables individuals to become more resistant to stress factors (Basso and Suzuki, 2017). Studies in the literature examine the effects of exercise on neurotransmitters in more detail. For example, in a study conducted on Parkinson's patients, it was determined that exercise increased dopamine transporter D2 receptor expression and thus improved motor functions (Fisher et al., 2008). In addition, it has been stated that exercise can relieve symptoms of depression by regulating serotonin levels. (Craft and Perna, 2004). Additionally, progressive relaxation exercises have been shown to contribute to the reduction of anxiety and stress by increasing GABA levels (Streeter et al., 2010).

In particular, aerobic exercises have been found to improve cognitive functions and attention processes by increasing norepinephrine levels (Mandolesi et al., 2018). In conclusion, research on exercise and neurotransmitter interaction reveals various effects of different types of exercise on the nervous system. In the light of this information, in this study, clinical and experimental studies on the effects of exercise on neurotransmitter levels were systematically examined and the contributions of different exercise types and intensities to these biochemical processes were evaluated.

METHOD/METHOD

The research model

This systematic review was conducted based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline. Leading databases such as Google Scholar, PubMed, Web of Science, Scopus and PsycINFO were used for literature review and studies published between 2015-2025 were included. Keywords such as "exercise", "neurotransmitter", "dopamine", "serotonin", "GABA" and "norepinephrine" were used in the screening strategy.

Criteria for inclusion in the research:

1. Studies examining the effect of exercise on neurotransmitter levels,
2. Reviews, studies using experimental or clinical design,
3. Articles published in English or Turkish.

Exclusion criteria:

1. Animal studies,

2. Studies addressing interventions other than exercise.

As a result of the literature review, 213 studies were reached. As a result of the restrictions, a total of 9 studies were included in the research. The selected studies were evaluated in terms of method, findings and results and are listed in the table below.

Analysis

In this systematic review, the selected studies were examined according to predefined inclusion and exclusion criteria. The fundamental information of each study (author, year, sample, type of exercise, duration, measured neurotransmitters, and findings) was tabulated and descriptively summarized. The relationships between exercise and neurotransmitter levels were then categorized thematically and interpreted by considering the differences and similarities between the studies.

RESULTS

Table 1. Analysis of Reviewed Studies

Study	Participants	Method	Main Findings
Maddock ve ark. (2016)	38 healthy individuals (18-35 years old)	Cortical GABA and glutamate measurements with ^{1}H-MRS	It was determined that there was a significant increase in GABA and glutamate levels after exercise.
Guimarães see ark. (2024)	60 sedentary women (35-55 years old)	GABA supplementation + exercise, HRV and psychological effects measured	It was stated that HRV and sleep quality increased and depression decreased in the group receiving GABA supplements.
Teixeira and Arch. (2021)	13 young and healthy individuals	GABAA receptor activation and sympathetic nervous system measurement	It has been stated that GABAA activation suppresses sympathetic responses.
Lyssikatos ve ark. (2023)	120 individuals	Serum GABA and L-AABA measurements + physical performance tests	While GABA level increased with age, physical performance decreased, and L-AABA was found to be associated with performance.
Di Liegro et al. (2019)	Literature compilation	Effects on neuroplasticity, neurogenesis and inflammation were examined	It has been stated that exercise supports brain health by increasing neurotrophic factors.
Mahalakshmi and the arch. (2020)	Literature compilation	Neuroprotective mechanisms of exercise were examined	It has been stated that exercise provides neuronal protection by increasing neurotransmitter production.

Boecker ve ark. (2023)	20 trained athletes	rs-fMRI ile fALFF analizi, PANAS testi	After HIIE, fALFF changes and positive emotion scores were observed in brain regions related to dopamine and μ-opioid receptor distributions.
Teo et al. (2024)	healthy individuals	Oxygenated hemoglobin (HbO) measurement in M1 and DLPFC with fNIRS	While high-intensity contractions increased M1 and DLPFC activation, no significant difference was found between concentric and eccentric contractions.
Erdogan & Aslan (2021)	Literature compilation	Homeostatic physiological effects of exercise were examined	It has been stated that exercise increases cognitive processing speed and reduces stress hormones by increasing serotonin and noradrenaline levels.

DISCUSSION

This systematic review was conducted to examine the effects of exercise on neurotransmitter systems. As a result of a comprehensive literature review in leading databases such as Google Scholar, PubMed, Web of Science, Scopus and PsycINFO, nine (9) academic studies were included in the review using the keywords "exercise", "neurotransmitter", "dopamine", "serotonin", "GABA" and "norepinephrine". Maddock et al. (2016) study, proton magnetic resonance spectroscopy (^{1}H-MRS) method was used to examine the acute effects of exercise on cortical neurotransmitter levels. In the study, significant increases in glutamate and GABA levels in the visual cortex and anterior cingulate cortex were observed after intense exercise. These findings indicate that exercise modulates neurotransmitter dynamics by directly affecting brain metabolism and that this mechanism may be important in neurodegenerative diseases, neurorehabilitation processes and aging-related cognitive changes. Similarly, Guimarães et al. (2024) examined the physiological and psychological effects of GABA supplementation on sedentary and overweight women in a placebo-controlled, randomized clinical study. Participants participated in a regular exercise program for 12 weeks, and significant improvements were observed in parameters such as heart rate variability (HRV), emotional response, sleep efficiency and depression levels in the group receiving GABA supplements. Findings suggest that GABA supplementation potentiates the positive effects of physical exercise and offers potential benefits in areas such as depression treatment, stress management, and sleep disorders. Teixeira et al. (2021) study examined how muscle sympathetic nerve activity (MSNA) was modulated by GABA receptor activation during static

exercise. Findings have shown that GABA receptor activation contributes to the autonomic control mechanisms of the central nervous system by suppressing sympathetic nervous system responses. This study highlights the critical role of GABA receptors in cardiovascular regulation during exercise. Lyssikatos et al. (2023) examined the relationship of GABA and L-α-aminobutyric acid (L-AABA) levels with physical performance and aging. The study determined that high GABA levels were associated with low physical capacity, whereas L-AABA levels were higher in individuals with better physical performance. It was found that the GABA/L-AABA ratio showed a strong relationship with physical performance measures, especially in male participants. Di Liegro et al. (2019) study, the positive effects of exercise on brain plasticity, neurogenesis and the release of neurotrophic factors were emphasized. Research reveals that exercise supports brain health by reducing inflammation and controlling oxidative stress Mahalakshmi et al. (2020) focused on the potential protective effects of exercise in neurodegenerative diseases. The study stated that exercise supports neuronal survival and neuroplasticity by increasing the production of neurotrophic factors, neurotransmitters and hormones. Additionally, it has been stated that exercise optimizes neuroendocrine and physiological responses to psychosocial and physical stress. Wei-Peng Teo et al. (2024) study, changes in brain activation during different intensities and contraction types of the biceps brachii muscle were examined. In measurements using functional near-infrared spectroscopy (fNIRS), it was observed that high-intensity contractions caused greater activation in the motor cortex and dorsolateral prefrontal cortex. This finding suggests that high-intensity exercise can be used in neurorehabilitation programs. Henning Boecker et al. (2023) examined the fractional amplitude (fALFF) of low-frequency fluctuations associated with endocannabinoid, μ-opioid, and dopamine receptor distributions in the central nervous system of high-intensity exercise sessions. Findings showed fALFF changes in some brain regions after high-intensity interval exercise, supporting the effects of exercise on dopaminergic and μ-opioidergic systems. Finally, in the study of Erdoğan and Aslan (2021), it was stated that regular physical activity contributes to the acceleration of cognitive processes and improvement of mood by increasing the release of serotonin and noradrenaline. It has also been stated that it helps maintain homeostatic balance by reducing the level of stress hormones. In conclusion, the studies reviewed reveal the versatile effects of exercise on neurotransmitter systems. Exercise produces positive results in a wide range of areas, from cortical neurotransmitter levels to autonomic nervous system responses, from neuroplasticity mechanisms to psychological well-being. These findings support the potential role of physical activity in neurodegenerative diseases, cognitive functions, stress management and mood regulation.

Conclusion and Recommendations

The studies included in the review show that exercise creates consistent and positive effects on neurotransmitter levels. In particular, it has been observed that aerobic exercises improve mood and relieve symptoms of stress and depression by increasing serotonin and norepinephrine levels. Anaerobic exercises such as high-intensity interval training (HIIT) strengthen cognitive functions, attention and motivation by increasing the release of dopamine and norepinephrine. Additionally, strength training has been found to reduce anxiety levels and calm the nervous system by increasing GABA activity. These findings support that exercise plays an important role not only in physical health but also in mental and psychological well-being. By modulating neurotransmitter systems, exercise contributes to individuals' improvement in areas such as stress management, mood regulation and cognitive performance. As a result, optimizing neurotransmitter levels of exercise programs shows that it will affect mental and physical performance. However, it has been emphasized that factors such as timing, frequency and duration of exercise also affect its effects on neurotransmitters and that more temporal resolution research is needed in this area..

Researchers In The Statement Of Participation Rates

At all stages of the research authors contributed equally.

Statement Of Conflict

It is not a conflict with a declaration of the author of the research.

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