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The Medical Interventions of Exercise on Mental Health: Mechanisms and Theoretical Effects

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ABSTRACT
With the increasing severity of mental health problems, traditional drug therapy and psychotherapy have certain limitations in terms of intervention effects and side effects. Exercise, as a new means of mental health intervention, has been widely concerned. This paper discusses the mechanism and theoretical effect of exercise intervention on mental health from a medical point of view. Firstly, the effect of exercise on improving mental health through neurophysiological mechanism, psychological and cognitive mechanism, immune and inflammatory mechanism was analyzed. Secondly, the effects of different forms of exercise such as aerobic exercise, resistance training and mindfulness exercise were compared, and the effects of exercise intensity, frequency, duration and environmental factors were pointed out. Finally, this paper summarizes the limitations of the current research, and proposes that future research should focus on the development of multi-disciplinary and personalized exercise intervention strategies to achieve more effective mental health intervention. The results of this study provide theoretical support for the application of exercise in the field of mental health, and provide reference for future clinical practice and intervention program design.

KEYWORDS
Exercise intervention; Mental health; Neural mechanisms; Immune mechanisms; Personalized intervention

1 Introduction

In the social background of globalization and accelerated urbanization, mental health problems are increasingly common and have become an important public health issue threatening human health. According to the report of the World Health Organization, mental illnesses such as depression and anxiety disorders affect more than 1 billion people worldwide, and show a trend of young and chronic development. Psychological problems not only significantly reduce the quality of life of individuals, but also are highly related to a variety of physical diseases such as cardiovascular disease and immune dysfunction, and also cause a heavy burden on the social and economic system [1].

At present, the interventions for mental health problems mainly include drug therapy and psychotherapy. Drug intervention can control symptoms by modulating neurotransmitters. Although the effect is faster, there are significant side effects, strong dependence and high recurrence rate. Psychotherapy, such as cognitive behavioral therapy and humanistic therapy, relies on professional resources to establish therapeutic relationship, which has a long cycle and high cost. In this context, non-drug and non-invasive alternative therapy has become a research hotspot, among which exercise intervention has attracted wide attention due to its high feasibility, low cost and low side effects.

A large number of studies have shown that regular physical activity can not only improve emotional state, relieve anxiety and depression symptoms, but also play a positive role in psychological intervention by regulating neurotransmitters, enhancing brain plasticity, improving immune system function and other multiple physiological mechanisms. This dual value of exercise-both to promote physical health and to improve mental status-makes it unique in the system of medical intervention.

Based on this, this paper aims to systematically explore the intervention mechanism and theoretical effect of exercise on mental health. From the perspectives of neurophysiology, cognitive psychology and immune regulation, this paper analyzes how exercise affects mental disorders at the medical level, and then provides theoretical support for the expansion and optimization of future mental health interventions.

2 Basic concepts and main problems of mental health

Mental health is an important part of the overall health of human beings, and its connotation goes far beyond disease-free state. According to the definition of the World Health Organization (WHO), mental health is not only the absence of mental disorders, but also includes the individual's cognitive, emotional and behavioral functioning in a good state, able to cope with daily stress, competent work, establish positive relationships with others and make effective contributions. From a clinical perspective, the Diagnostic and Statistical Manual of Mental Disorders (DSM) defines mental health as a

state in which an individual's cognitive, emotional and behavioral performance does not deviate significantly from sociocultural expectations. And no sustained functional impairment [2].

In clinical practice, common mental health problems mainly include depression, anxiety disorder and post-traumatic stress disorder (PTSD). Depression is characterized by persistent low mood, loss of interest, lack of energy and cognitive retardation. In severe cases, self-injury and even suicide may occur. Anxiety disorders are characterized by persistent stress, fear, and physical overactivation, often accompanied by sleep disturbances and decreased concentration. Stress-related disorders, such as acute stress response or PTSD, usually result from a major negative event, the consequences of which can have a long-term impact on an individual's nervous system and psychological resilience.

Mental health disorders are not only emotional abnormalities, but also lead to a series of physiological and social dysfunction. In terms of physiology, studies have found that psychological diseases are closely related to cardiovascular diseases, endocrine disorders, and low immune function[3]. Long-term depression and chronic stress can lead to dysfunctions of the hypothalamic-pituitary-adrenal axis (HPA axis), which can affect the stability of multiple systems in the body. In terms of social function, patients with mental disorders are often restricted in different degrees in learning, work, family relations, etc., which is easy to cause social isolation, unemployment and even economic difficulties, forming a bad cycle of "psychological - physiological - social" three-dimensional intersection.

Therefore, a deep understanding of the concept and types of mental health problems is a prerequisite for effective intervention and scientific treatment. Based on this basis, this paper will further explore the mechanism and theoretical value of exercise in the intervention of mental health problems.

3 Medical basis and theoretical mechanism of sports intervention

3.1 Neurophysiological mechanism

The positive effects of exercise on mental health have a solid scientific basis at the neurophysiological level. Several neuroscience studies have shown that regular physical activity can improve emotional state, relieve psychological stress, and combat common psychological disorders such as anxiety and depression by regulating neurotransmitter secretion, promoting neuroplasticity, and regulating the function of the hypothalamic-pituitary-adrenal axis (HPA axis) [4].

First, exercise can significantly regulate the levels of neurotransmitters in the central nervous system. Serotonin, dopamine, and norepinephrine are key chemicals in mood regulation. Studies have found that aerobic exercise can promote the synthesis and release of serotonin, enhance emotional stability, and reduce depressive symptoms. The activation of the dopamine system helps to improve motivation and reward responses, while the upregulation of norepinephrine enhances attention and alertness, improving cognitive delays in anxiety disorders. These regulatory effects constitute an important basis for exercise intervention in emotional disorders.

Second, exercise promotes the expression of Brain-Derived Neurotrophic Factor (BDNF), a protein that maintains neuron survival, promotes synaptic plasticity, and is considered a marker for brain plasticity. In people with depression, BDNF levels decline. Exercise, especially sustained aerobic exercise, can significantly increase BDNF expression in the hippocampus and prefrontal cortex, enhancing neural network recovery. This mechanism is a core aspect of the antidepressant effect of exercise [5].

Additionally, exercise plays a key role in regulating the HPA axis, which is the core endocrine pathway in response to stress. In chronic stress or mood disorders, the HPA axis is often highly activated, leading to elevated cortisol levels, neurotoxicity, and immune dysfunction. Regular exercise can reduce the activation of the HPA axis, improve endocrine balance, and relieve stress. Studies have shown that exercise can effectively reduce cortisol concentration under chronic stress, stabilize mood fluctuations, and enhance emotional regulation.

3.2 Psychological and cognitive mechanisms

In addition to physiological regulation, exercise intervention has significant psychological and cognitive benefits [6]. It enhances self-efficacy, promotes achievement experiences, improves emotional regulation, and reduces negative cognition, helping individuals restore a sense of control and positive self-evaluation, thereby alleviating psychological symptoms and improving resilience.

Exercise strengthens self-efficacy, which is an individual's belief in their ability to handle tasks or stress. Consistent exercise helps achieve goals (e. g., completing a run, improving fitness), boosting self-perception and breaking the negative cycle of "incompetence and low self-esteem."

Regular exercise fosters a sense of achievement through tangible improvements like increased endurance and emotional stability. Unlike passive treatments, exercise provides active feedback, stimulating intrinsic motivation and promoting positive psychological change. This approach aligns with cognitive behavioral therapy's use of positive reinforcement.

Exercise also helps break negative cognitive patterns, such as excessive worry and self-denial, by shifting attention to physical movements and external stimuli, providing a "breathing space" for cognitive dissociation. Additionally, the release of endorphins and dopamine during exercise alleviates negative emotions and improves cognitive flexibility.

Furthermore, exercise enhances emotional regulation. For instance, aerobic exercise increases prefrontal cortex activity, which helps control emotional responses in the amygdala, strengthening mental resilience in the face of negative stimuli. This ability to regulate emotions is vital for mental health, particularly in the rehabilitation of mood disorders.

3.3 Immune and inflammatory mechanisms

In recent years, research on the intersection between the immune system and mental health has been deepening, revealing a close physiological link between chronic inflammatory responses and mood disorders. Among them, psychological disorders such as depression and anxiety have been shown to be associated with systemic low-grade inflammation to a certain extent. Exercise, as a non-drug intervention to regulate immune function, has shown significant potential in inflammation regulation and psychological improvement.

First, regular exercise has been shown to effectively regulate the expression levels of various inflammatory factors, such as Interleukin-6 (IL-6) and Tumor Necrosis Factor-alpha (TNF- α). In patients with mental illness, these pro-inflammatory factors are often in an abnormally elevated state, damaging nerve cell function, interfering with neurotransmitter balance, and thus aggravating emotional disorders. Moderate exercise can induce anti-inflammatory signaling pathway through muscle activity, increase the secretion of anti-inflammatory factors such as IL-10, and inhibit the production of pro-inflammatory molecules such as TNF-α and C-reactive protein (CRP), thus reducing the damage of chronic inflammatory response to the central nervous system.

More and more evidence suggests that inflammatory states play an important role in the pathogenesis of depression. Studies have found that exogenous inflammatory inducers can cause depression-like behavior in laboratory animals, and anti-inflammatory drugs have shown some efficacy in some patients with depression. This "inflammation hypothesis" suggests that inflammatory factors can indirectly trigger or exacerbate depressive symptoms by disrupting the blood-brain barrier, activating microglia, and interfering with monoamine neurotransmitter metabolism. Therefore, reducing the level of inflammation in the body through exercise can not only improve the overall immune environment, but also indirectly promote emotional stability and psychological repair[7].

What's more, the effect of exercise on immune function is "dose-dependent." Moderate intensity, regular aerobic exercise is the most helpful to reduce the level of inflammation, while excessive high intensity exercise may cause stress inflammatory response. Therefore, the development of scientific and individualized exercise intervention programs can not only effectively activate the immune regulatory function, but also avoid additional body burden.

4 Comparison of theoretical effects of different types of exercise interventions

Different types of exercise intervention show the effect and mechanism of alienation in improving mental health. According to the different intensity, form and intervention target, aerobic exercise, resistance training (strength training) and mindfulness exercise have different emphasis on emotional regulation, cognitive function improvement and stress response control.

The following will discuss the intervention characteristics of the three main types of exercise respectively, and compare the theoretical effects through the table.

4.1 Aerobic Exercise

Aerobic exercise, such as running, swimming, brisk walking, etc., has been widely proven to be effective in reducing depression, anxiety and other mood disorders. Its main mechanism is to promote the secretion of neurotransmitters related to mood regulation such as serotonin and norepinephrine, enhance the stability of the autonomic nervous system, and improve cardiorespiratory function, so as to have a positive impact on mental health. Long-term regular aerobic exercise can also maintain emotional stability and reduce physiological stress response.

4.2 Resistance Training (Strength Training)

Resistance training improves mental state by enhancing muscle strength and fitness, improving body image and self-efficacy.

This form of training can enhance the functional connectivity of the prefrontal cortex and hippocampus, promote the release of nerve growth factors such as BDNF, and help improve cognitive function, especially in the elderly population. Strength training also has positive effects on self-esteem and mood regulation.

4.3 Mindfulness-based exercises

Mindfulness-based exercises (such as yoga, tai chi, and mindfulness meditation) combine physical movement with mental training to emphasize awareness and acceptance of the present moment. Its intervention mechanism not only includes regulating the balance of sympathetic and parasympathetic nerves to relieve physiological stress, but also involves the enhancement of prefrontal cortex activation and neuroplasticity, which helps to relieve chronic stress, anxiety and negative emotions. Its unique dual neuromodulation effect makes it outstanding in the intervention of mood disorders.

Table 1 Comparison of theoretical mechanisms and effects of different types of exercise interventions

Types of Exercise	Main intervention mechanisms	Areas of mental health impact	Characteristics and advantages
Aerobic Exercise	Enhances neurotransmitter activity (e.g., serotonin, norepinephrine), modulates the HPA axis, and regulates autonomic nervous function.	Alleviates anxiety and depression, and improves emotional stability	Suitable for most populations with a low intervention threshold
Resistance Training (Strength Training)	Improve BDNF level, enhance prefrontal functional connectivity, and enhance self-efficacy	Improve self-esteem, enhance cognitive ability, emotional regulation	Particularly effective in improving cognitive function and body image
Mindfulness-based exercises	Increased neuroplasticity, prefrontal activation, and nervous system rebalancing	Reduce stress, enhance emotional regulation and mindful perception	Both physical and mental adjustment function, suitable for emotional stress people

5 Key factors affecting the effect of exercise intervention

The effect of exercise intervention is not only affected by the type of exercise, but also closely related to individual differences, exercise intensity, exercise duration and environmental factors. Understanding these key factors can help to develop more precise exercise intervention programs for different groups to achieve the best mental health improvement effects.

5.1 Individual differences: age, gender, psychological basis

Individual differences are important factors that affect the effect of exercise intervention. Age is one of the key variables. For the young group, exercise may be more likely to improve self-efficacy and cognitive function, while for the elderly group, exercise has a particularly significant intervention effect on cognitive ability, emotional stability and senile depression. Gender is also a factor to watch. Studies have shown that there may be differences in physiological response, psychological response and movement behavior habits between men and women during exercise intervention. For example, women may be more likely to experience a boost in mood when doing aerobic exercise, while men may get more of a self-esteem boost during strength training.

In addition, the individual's psychological basic state (such as existing psychological disorders, emotional health level, etc.) will also affect the effect of exercise intervention. Individuals with existing symptoms of depression or anxiety tend to experience more significant changes in mood during exercise intervention, while individuals with good mental health may benefit more from the improvement of cognitive regulation and physical health from exercise.

5.2 Dose effect of exercise intensity and frequency

The intensity and frequency of exercise have significant dose effect on the intervention effect. Moderate exercise intensity and frequency have the best effect on mood improvement and mental health recovery. Studies have shown that moderate-intensity aerobic exercise, such as brisk walking and jogging, can effectively improve mental state and relieve symptoms of anxiety and depression. However, excessive exercise intensity can lead to excessive fatigue or stress responses in the body, which can negatively affect mental health. Therefore, it is important to control the intensity and frequency of exercise reasonably, and individualized exercise program can ensure the best intervention effect.

5.3 Duration and habit formation

The duration of exercise intervention and whether individuals can form exercise habits directly affect the sustainability of the effect. Short-term exercise intervention may only bring temporary psychological improvement, while long-term regular exercise can help individuals maintain a more stable state of health in physiological, psychological and emotional dimensions. Individuals who adhere to exercise for a long time are usually able to better manage stress, improve emotional regulation, and further enhance their sense of self-efficacy through the formation of exercise habits.

5.4 Environmental factors: group vs individual, voluntary, etc

Environmental factors also have important influence on the effect of exercise intervention. There are differences in mental health improvement between team sports and individual sports. Team sports provide social interaction, team support and collective motivation, which can enhance individuals' sense of belonging and self-efficacy. Especially for those individuals with a tendency to be socially isolated, the intervention effect of team sports is more significant. Individual exercise, on the other hand, is more flexible and suitable for individuals who prefer independent and personalized interventions.

6 Conclusion and prospect

As a non-drug mental health intervention, exercise has become an important tool for improving mood, regulating cognitive function, and alleviating anxiety and depression symptoms. Through mechanisms like neurophysiological, psychological, and immune regulation, exercise not only enhances psychological well-being but also promotes physical health, offering comprehensive support for overall mental health improvement.

However, current research has limitations. There is no unified theoretical framework for the mechanisms of exercise intervention, and the relationship between neurobiology, psychology, and immunology needs further clarification. Additionally, most studies focus on single types of exercise, lacking comprehensive, personalized intervention programs.

Looking ahead, multidisciplinary research combining psychology, neuroscience, and biomedical science will provide deeper insights into how exercise affects mental health. With advancements in sports science and psychology, personalized exercise strategies tailored to individual mental health, physical conditions, and social environments will be developed to maximize intervention effects.

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