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Exercise and The Mind: Exploring Psychophysiological Mechanisms Underlying The Mental Health Benefits of Physical Activity

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ABSTRACT

Exercise or Physical activity (PA) is increasingly recognized as a potent, multidimensional intervention for promoting mental health and mitigating symptoms of stress, anxiety, and depression. This review synthesizes evidence from psychophysiological and biopsychosocial perspectives, highlighting the mechanisms through which exercise influences mental well-being. Chronic exercise modulates neuroendocrine function, reduces systemic inflammation, enhances brain-derived neurotrophic factor (BDNF), and improves autonomic balance, collectively supporting neuroplasticity and emotional regulation. Concurrently, psychological benefits such as increased self-efficacy, body image, coping skills, and reduced depressive and anxiety symptoms are reinforced, particularly in group-based settings that foster social support, cohesion, and exercise identity. Integrating these biological, psychological, and social pathways, physical activity functions as a sustainable, non-pharmacological strategy to optimize long-term mental health outcomes. This multidimensional model underscores the critical role of structured exercise interventions as an accessible and scalable approach to enhance resilience and overall well-being across populations.

1. INTRODUCTION

Mental health disorders, including depression, anxiety, and chronic stress, constitute a growing global burden. For example, systematic reviews indicate that the worldwide prevalence of common mental disorders reaches double-digit percentages of the adult population [1]. Furthermore, factors such as socioeconomic burden, lifestyle changes, and constant technology consumption are believed to contribute to exacerbating these conditions. While traditional interventions such as pharmacological therapy and psychotherapy play an important role in the management of mental disorders, they still have limitations. For example, response to antidepressants or cognitive-behavioral therapy can vary between individuals, pharmacological side effects, and access to adequate psychotherapy remains a barrier. Therefore, there is a need for complementary or alternative strategies that can strengthen intervention outcomes and optimize mental health sustainably.

In this context, physical activity or sport is beginning to be recognized as "medicine for the mind," not only for physical health but also for mental health. Research shows that regular exercise can reduce symptoms of depression and anxiety, improve general well-being, and provide a protective effect against chronic stress [2]. However, a comprehensive understanding of how exercise affects mental health, particularly through interconnected biological and psychological mechanisms, remains elusive. Although numerous studies have demonstrated the benefits of exercise on mental health, most have addressed these effects separately: for example, studies focusing on neuroendocrine or inflammatory mechanisms, and studies separately on psychological aspects such as self-esteem or coping. However, relatively few reviews systematically integrate both biological and psychological domains within a psychophysiological framework linking exercise, body mechanisms, psychological processes, and mental health outcomes.

The importance of this integrative approach lies in the fact that biological mechanisms (e.g., changes in stress hormones, inflammatory cytokines, neurotrophic factors) do not exist in isolation but rather interact with psychological mechanisms (e.g., emotion regulation, self-concept, coping strategies) in determining how exercise can affect mental health. For example, studies have shown that exercise can strengthen neuroplasticity factors (e.g., brain-derived neurotrophic factor (BDNF), which in turn can support changes in psychological well-being [3]. Furthermore, exercise can moderate the response of stress hormone systems (e.g., the hypothalamic-pituitary-adrenal axis (HPA axis)) and inflammation, which are then associated with improved mood and reduced depressive symptoms [4]. With the increasing prevalence of mental health disorders worldwide and the limitations of conventional interventions, research on exercise as a non-pharmacological strategy is becoming increasingly important. By understanding how exercise works at both the mind and body levels, we can strengthen the evidence base for its use as an integral component in the promotion and maintenance of mental health. Therefore, this paper is expected to make a significant contribution to synthesizing the scattered literature and paving the way for more comprehensive interventions.

2. CONCEPTUAL FRAMEWORK: THE PSYCHOPHYSIOLOGICAL MODEL

Psychophysiology explores the close and ongoing relationship between the mind and the body, focusing on how mental experiences such as thoughts, emotions, and behaviors are reflected in physiological processes. Rather than viewing psychological and physical functions as separate, this field examines how changes in behavior and mental states are accompanied by measurable bodily responses. This perspective helps explain why exercise is such an effective means of mind–body interaction. Physical activity does more than produce physical benefits; it also positively influences mood, thinking ability, and emotional regulation [5]. Through exercise, several biological systems are activated at once, including the release of neurotransmitters, hormonal changes, and adjustments in the autonomic nervous system. Together, these responses help reduce stress, support emotional balance, and improve behavioral regulation [6].

Physical activity is widely recognized as an effective strategy for supporting mental well-being and reducing the risk of mental health disorders. Along with its clear physical advantages, regular exercise has a meaningful impact on mood and cognitive performance. A substantial body of research consistently shows that exercise enhances both emotional states and cognitive functioning. Because of these broad and reliable benefits, exercise is increasingly recommended as a versatile and accessible intervention. Psychophysiology provides the theoretical foundation for understanding how these benefits arise through the interaction between mental processes and bodily systems. Within this framework, exercise stands out as a powerful intervention because it naturally integrates physical movement with psychological change. One key biological pathway underlying the mental health benefits of exercise involves Brain-Derived Neurotrophic Factor (BDNF). BDNF is a protein abundant in the central nervous system, particularly in regions such as the hippocampus, cerebral cortex, hypothalamus, and cerebellum, where it plays a crucial role in brain function. Research indicates that physical activity is an effective means of increasing BDNF activity in humans [7]. From a psychophysiological perspective, the mental health benefits of exercise clearly extend beyond improvements in physical fitness alone, highlighting the underlying mechanisms as an important and multidimensional area for continued research.

The Biopsychosocial (BPS) model offers a comprehensive way to understand how physical activity supports mental health by considering the combined influence of biological, psychological, and social factors. Rather than focusing on a single pathway, the BPS framework acknowledges that exercise produces direct physiological effects—such as improvements in cardiovascular function and changes in neuroendocrine activity—while also generating important psychological and social benefits, including increased self-esteem and stronger social connections. This integrative approach is strongly supported by research, with recent systematic reviews consistently showing that interventions targeting multiple domains lead to greater mental health improvements than those addressing isolated symptoms alone [8, 9]. From a biological perspective, regular physical activity influences key neurotransmitter systems, reduces inflammation throughout the body, promotes neurogenesis, and helps regulate the hypothalamic–pituitary–adrenal (HPA) axis. These physiological adaptations are linked to reductions in symptoms of depression and anxiety, as well as improved resilience to stress. Additionally, exercise-related increases in brain-derived neurotrophic factor (BDNF) and endorphin release play a direct role in enhancing mood, cognitive performance, and overall psychological well-being.

Psychologically, physical activity strengthens factors such as self-efficacy, body image, and feelings of achievement and mastery, all of which contribute significantly to improved mental health outcomes. Regular engagement in exercise has also been associated with the development of valuable psychological resources, including better coping strategies, improved emotional regulation, and greater mindfulness [9, 10, 11]. On a social level, exercise particularly when carried out in group or community settings creates opportunities for social interaction, support, and a sense of belonging. These social benefits are powerful influences on mental health, acting both as pathways through which exercise exerts its effects and as factors that can enhance or buffer those effects [8,11].

3. BIOLOGICAL MECHANISMS LINKING EXERCISE AND MENTAL HEALTH

Hypothalamic – Pituitary – Adrenal (HPA) Axis

The Hypothalamic - Pituitary - Adrenal (HPA) Axis is a central neuroendocrine system that plays an essential role in regulating the body's responses to physical and psychological stress through cortisol secretion. Restoring or maintaining normal HPA-axis function is crucial, particularly within the context of "Exercise and the Mind," because HPA-axis dysregulation characterized by elevated basal cortisol or an irregular stress response is associated with disrupted homeostasis, increased risk of non-communicable diseases, and psychological disorders such as obesity and PTSD. Normalization refers to restoring optimal resting HPA-axis integrity and optimizing its responsiveness to stressors [12, 13]. At the onset of exercise, physical activity acts as a potent physiological stressor that disrupts homeostasis and activates the HPA axis. This activation is characterized by the release of corticotropin-releasing hormone (CRH), adrenocorticotropic hormone (ACTH), and ultimately cortisol from the adrenal cortex. The cortisol response is highly dependent on the intensity and duration of activity. Classical research has established that the minimum intensity threshold required to elicit an HPA-axis mediated cortisol response is approximately 60% of VO_2max, above which cortisol levels increase linearly. Conversely, low-intensity exercise may lead to a post-exercise decrease in cortisol, as metabolic clearance exceeds adrenal secretion.

Clinical studies in obese women, who typically demonstrate heightened HPA-axis activity, show that both interval and continuous moderate-intensity aerobic exercise significantly reduce cortisol secretion and HPA-axis activity immediately after an acute session. These findings suggest that exercise is an effective model for reducing stress and mitigating HPA-axis hyperactivity [14]. Regular (chronic) aerobic exercise is believed to mediate reductions in cortisol levels through two primary mechanisms: adjustments in cortisol metabolism and adaptations in stress reactivity. First, during low to moderate intensity exercise, the post-exercise decrease in cortisol concentrations is attributed to an increase in metabolic clearance (cellular uptake) of cortisol that exceeds adrenal secretion, rather than a reduction in steroidogenesis [13, 15]. Second, long-term adaptations alter the overall regulation of cortisol within the body. Endurance-trained individuals generally exhibit normal resting HPA-axis function, with morning plasma cortisol concentrations, daily rhythms, and 24-hour urinary free cortisol (UFC) excretion comparable to those of untrained subjects. This indicates that 24-hour HPA-axis activity is not chronically elevated in trained individuals [14].

4. ENHANCED PARASYMPATHETIC TONE AND REGULATION OF THE AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system (ANS), which consists of the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS), plays a fundamental role in maintaining health by continuously adjusting cardiovascular and metabolic function to meet the body's demands [16]. Under resting conditions, parasympathetic activity often referred to as vagal tone predominates and is primarily responsible for regulating heart rate. During exercise, however, sympathetic activity progressively increases to support the physiological demands of physical exertion (17). Parasympathetic activity can be assessed non-invasively using heart rate variability (HRV). Common indicators of vagal modulation include time-domain measures such as the root mean square of successive differences (RMSSD) and the proportion of NN50 intervals (pNN50), as well as frequency-domain measures such as high-frequency (HF) power.

Acute exercise and the period immediately following it are characterized by rapid changes in autonomic regulation. The initial increase in heart rate, up to approximately 100 beats per minute, is largely driven by withdrawal of parasympathetic influence, while further increases at higher exercise intensities are mainly due to heightened sympathetic activation [16]. Evidence from a meta-regression analysis examining ANS responses during exercise and within one hour after exercise (WHAE) demonstrated a significant reduction in parasympathetic activity, reflected by decreased RMSSD, along with a near-significant increase in sympathetic dominance as indicated by the LF/HF ratio in adults [17]. The effects are even more pronounced following exhaustive exercise, which leads to marked suppression of parasympathetic indices, including substantial reductions in RMSSD and pNN50 sometimes by as much as 94.55%, suggesting profound vagal inhibition [18].

Interestingly, findings from direct neurophysiological studies in animal models present a contrasting perspective. These studies show that central vagal drive, measured through the activity of vagal preganglionic neurons, actually increases during acute exercise, challenging the traditional view that exercise is associated with central vagal withdrawal [19]. After exercise cessation, parasympathetic reactivation becomes the dominant feature of early recovery, and heart rate recovery (HRR) is widely recognized as a simple yet reliable marker of parasympathetic function. In contrast to the transient autonomic shifts seen with acute exercise, long-term endurance training leads to favorable adaptations that enhance parasympathetic tone and restore balanced autonomic regulation, particularly in individuals with autonomic dysfunction. Chronic exercise is associated with a relative dominance of parasympathetic activity, evidenced by lower resting heart rate (resting bradycardia) and increased HRV, including higher HF power and SDNN. As a result, trained individuals can perform absolute workloads with reduced sympathetic activation and less suppression of parasympathetic influence. This exercise-induced enhancement of vagal tone is cardioprotective and is thought to be driven by mechanisms such as increased nitric oxide (NO) bioavailability, which improves vagal responsiveness, along with reductions in oxidative stress and systemic inflammation [16].

5. ANTI-INFLAMMATORY MECHANISMS

Long-term physical exercise is an effective non-pharmacological strategy for reducing systemic inflammation in healthy individuals, as reflected by decreases in inflammatory markers such as interleukin-6 (IL-6), C-reactive protein (CRP), and tumor necrosis factor-α (TNF-α). Among these, reductions in IL-6 are considered central to the cardioprotective and anti-inflammatory effects of sustained physical activity and have been consistently observed across young, middle-aged, and athletic populations following both chronic training and moderate-intensity exercise (20).

Chronic exercise training (ET) also mitigates low-grade inflammation associated with *inflammageing*, a key risk factor for conditions such as type 2 diabetes, cardiovascular disease, and sarcopenia. Meta-analytic evidence indicates that long-term ET significantly lowers circulating IL-6 levels in healthy individuals (SMD = –0.16), with cohort studies further demonstrating reduced IL-6 concentrations among individuals adhering to physical activity guidelines over extended follow-up periods. In older adults, resistance training (RT) interventions likewise produce significant reductions in IL-6, and aerobic, resistance, and combined exercise modalities have all shown comparable anti-inflammatory efficacy [21, 22, 23].

The reduction of IL-6 with chronic exercise reflects its biphasic physiological role. While baseline IL-6 levels decline with regular training, acute exercise induces a transient increase in IL-6 release from contracting skeletal muscle, where it functions as a myokine. This short-term elevation promotes glucose regulation and stimulates the production of anti-inflammatory cytokines, particularly interleukin-10 (IL-10), which suppresses pro-inflammatory mediators such as TNF-α. Repeated exposure to these acute responses contributes to an overall anti-inflammatory adaptation. Additionally, moderate-intensity exercise reduces circulating leptin, an adipocytokine known to upregulate IL-6 expression, further supporting long-term inflammation control [24, 25].

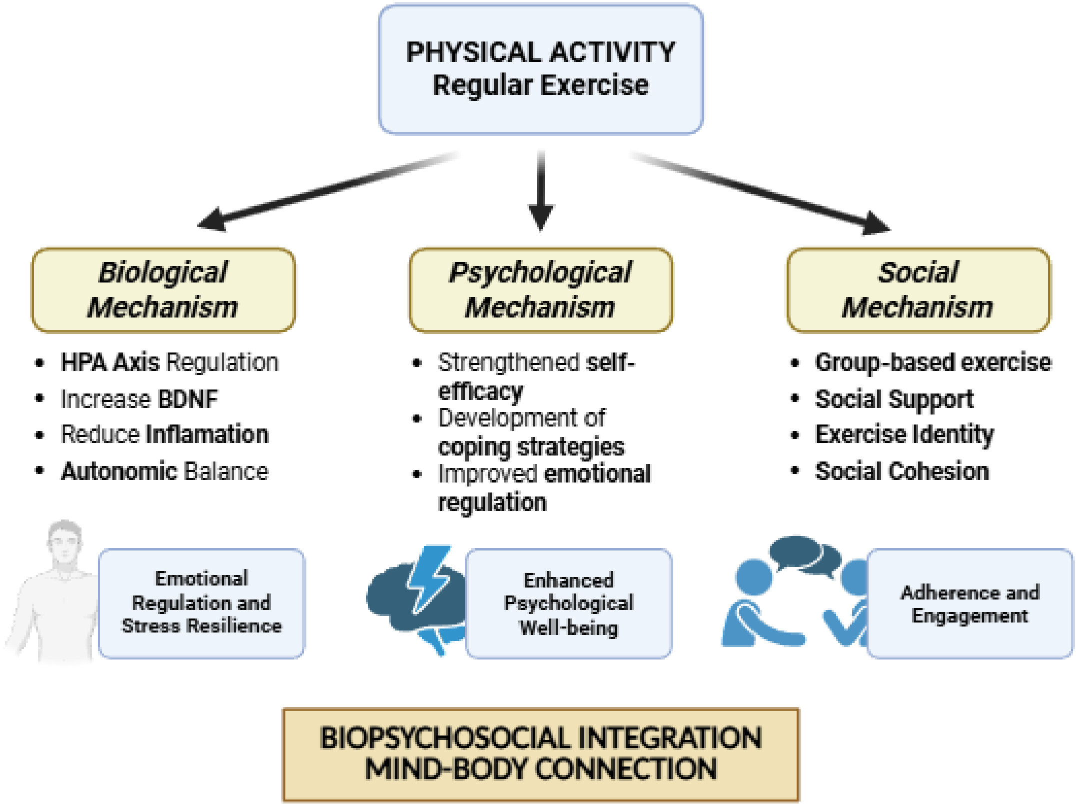

Figure 1. Physical activity promotes mental health through integrated biological, psychological, and social mechanisms. Exercise-induced adaptations in neuroendocrine, inflammatory, and autonomic systems interact with enhanced psychological resources and social support to support emotional regulation, resilience, and sustained mental well-being.

Exercise intensity and duration are key determinants of anti-inflammatory outcomes. Moderate-intensity exercise consistently produces anti-inflammatory effects, whereas high-intensity exercise may elicit pro-inflammatory responses. Training programs exceeding 12 weeks, and resistance training interventions lasting more than 16 weeks in older adults, are associated with greater IL-6 reductions. Combined training approaches appear to yield the most pronounced benefits. Acute evidence further supports these findings, with moderate-intensity exercise producing immediate reductions in serum IL-6 and facilitating muscle recovery. Overall, regular moderate-intensity physical activity is strongly recommended to maintain optimal inflammatory balance and metabolic health [20, 22, 24].

6. SOCIAL AND ENVIRONMENTAL FACTORS

Exercise is widely acknowledged not only for its physical health benefits but also for its substantial positive effects on mental health. It represents an effective, multidimensional approach for enhancing psychological well-being and alleviating symptoms of anxiety, stress, and depression. A comprehensive understanding of both external influences (social and environmental factors) and internal processes (psychological and mind–body mechanisms) that mediate and moderate these effects is essential for optimizing exercise-based interventions [26]. Group-based exercise has emerged as a particularly effective strategy for promoting sustained engagement in physical activity, largely due to the social cohesion and support inherent in group settings. Participation in group exercise programs is consistently associated with higher adherence rates compared to individually delivered interventions. These benefits are closely linked to multiple forms of perceived social support, including emotional, informational, validation, instrumental, and companionship support [27]. Social support plays a critical mediating role in the relationship between physical activity and mental health outcomes, contributing to reductions in depression, anxiety, and psychological distress, as well as improvements in overall well-being and life satisfaction among adults [28].

Beyond providing emotional reassurance, the social environment of group exercise actively shapes motivational processes and self-perceptions. Group contexts foster the development of key psychological resources, particularly self-efficacy and exercise identity [27]. Substantial evidence indicates that self-efficacy and self-esteem strongly mediate the association between physical activity and improved mental health outcomes, including decreased depressive and anxiety symptoms. Moreover, the shared experiences and positive reinforcement characteristic of group-based exercise strengthen exercise identity defined as the extent to which individuals perceive physical activity as part of their self-concept. In the general population, social support is positively associated with exercise identity, which in turn is strongly related to higher levels of weekly physical activity engagement [28].

7. CONCLUSION

The evidence synthesized in this review positions physical activity as a compelling psychophysiological intervention with broad relevance for addressing the global burden of mental health disorders. Through the coordinated modulation of neuroendocrine, immunological, and autonomic systems, chronic exercise contributes to the normalization of hypothalamic–pituitary–adrenal (HPA) axis function and the attenuation of systemic inflammation, including reductions in interleukin-6 (IL-6) and C-reactive protein (CRP), biomarkers frequently implicated in depression and chronic stress. Simultaneously, exercise-induced upregulation of brain-derived neurotrophic factor (BDNF) and enhanced parasympathetic activity, as indexed by increased heart rate variability, provide critical biological substrates for neuroplasticity, affect regulation, and stress resilience.

Importantly, these biological adaptations are embedded within a broader biopsychosocial context. Exercise strengthens key psychological determinants of mental health, including self-efficacy, body image, and adaptive coping capacity, while the social environment particularly in group-based modalities enhances adherence, fosters social cohesion, and consolidates a durable exercise identity. In light of the heterogeneous efficacy and accessibility of conventional pharmacological and psychological treatments, physical activity emerges as a scalable, cost-effective, and integrative non-pharmacological strategy. Embedding structured exercise interventions within mental health prevention and treatment paradigms offers a promising avenue for optimizing long-term mental health outcomes across diverse populations.

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CONFLICT OF INTEREST
The authors declared there is no conflict of interest.

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AUTHORS' CONTRIBUTION

Conceptualization of the framework: ASR & HAR. Data analysis, synthesis of the findings, and drafting of the manuscript: ASR, RM, SAKW. All authors (ASR, HAR, RM, SAKW, DCT) contributed and approved the final version of the manuscript.

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