

# **A Review of the Effects of Aerobic Exercise Intensity on Cognitive Function in College Students**

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**Abstract:** This study aims to review the impact of varying intensities of aerobic exercise on cognitive function in college students, providing a theoretical foundation for future research and practical applications. By synthesizing relevant domestic and international literature, the research focuses on the effects of three intensities of aerobic exercise—low, moderate, and high—on key cognitive functions such as attention, memory, and executive function. Utilizing a literature review methodology, the study systematically retrieves, screens, and reviews existing research, summarizing the differences in cognitive performance across different aerobic exercise intensities. Initially, the definitions and operational standards for different intensities of aerobic exercise are categorized and reviewed. Subsequently, the study conducts a detailed comparative analysis of the research findings on their cognitive effects. The systematic review reveals that low-intensity aerobic exercise can regulate and enhance emotional states and performance on simple cognitive tasks for some college students. Moderate-intensity aerobic exercise significantly enhances attention, memory, and executive function, making it the most effective intensity for improving cognitive function. High-intensity aerobic exercise shows significant short-term improvements in some cognitive functions, but its long-term effects and specific mechanisms require further investigation. The study also highlights the limitations of current research, such as small sample sizes and inconsistent methodologies, suggesting that future research should focus on increasing sample sizes, standardizing experimental protocols, and examining long-term effects. This review aims to provide theoretical support for higher education and mental health and to offer a reference for

developing scientifically sound exercise intervention policies for college students.

**Keywords:** Aerobic Exercise; Cognitive Function; College Students; Exercise Intensity

## **1. Introduction**

### **1.1 Research Background**

In recent years, there has been increasing scholarly interest in studying cognitive functions among college students due to its significant impact on their academic performance and quality of life. With the acceleration of life pace and increased academic pressure, cognitive issues like inattention, memory decline, and impaired executive function are becoming more prevalent in this demographic. These problems not only affect learning efficiency and academic performance but also pose risks to mental health and long-term development. Therefore, finding effective ways to enhance cognitive function in college students is critical. Aerobic exercise, widely recommended as a healthy lifestyle, is praised for its simplicity, low cost, and effectiveness. Numerous studies have demonstrated that aerobic exercise significantly benefits physical fitness and mental health. Some research also suggests that aerobic exercise positively impacts cognitive functions, particularly attention, memory, and executive function. However, the mechanisms through which different intensities of aerobic exercise affect cognitive functions are not well understood, and existing literature presents inconsistent findings. This study aims to review the specific impacts of various aerobic exercise intensities on cognitive functions in college students, providing a theoretical basis for future research and practical applications.

### **1.2 Research Objectives and Significance**

This study aims to analyze existing literature to explore the effects of different intensities of aerobic exercise on college students' cognitive functions. By examining the impact of low, moderate, and high-intensity aerobic exercise on attention, memory, and executive function, the study seeks to provide actionable exercise intervention recommendations for educators and mental health professionals. Understanding the mechanisms through which different intensities of aerobic exercise enhance cognitive functions will help develop scientifically sound exercise intervention programs. Additionally, the study addresses contemporary issues such as academic pressure and mental health in college students, encouraging their participation in aerobic exercise to improve overall physical and mental well-being.

## **2. Theoretical Basis of Aerobic Exercise and Cognitive Function**

### **2.1 Definition and Classification of Aerobic Exercise**

Aerobic exercise refers to moderate to low-intensity, prolonged activities performed with sufficient oxygen supply, engaging large muscle groups in rhythmic, continuous movements to improve cardiovascular fitness and physical health. Common forms include jogging, brisk walking, swimming, and cycling. Aerobic exercise can be classified based on the percentage of maximum heart rate:

Low-intensity aerobic exercise: 50%-60% of maximum heart rate, including activities like slow jogging and leisurely cycling.

Moderate-intensity aerobic exercise: 60%-70% of maximum heart rate, including brisk walking, rhythmic running, and skipping.

High-intensity aerobic exercise: Over 70% of maximum heart rate, including fast running, high-speed cycling, and high-intensity interval training.

Different intensities of aerobic exercise have varying effects on cardiovascular endurance, metabolic function, and muscle endurance, which may also differentially impact cognitive functions.

### **2.2 Definition and Classification of Cognitive Function**

Cognitive function encompasses the brain's processes for perceiving, memorizing, thinking,

and judging external information. It involves coordinated operations of multiple cognitive processes and abilities, including:

**Attention:** The ability to focus and selectively process specific information while shifting between different information sources. Enhanced attention significantly boosts learning and task execution efficiency.

**Memory:** The capacity to encode, store, and recall past experiences, categorized into short-term and long-term memory, and further into working memory, semantic memory, and episodic memory.

**Executive Function:** The ability to plan, organize, regulate, and execute goal-directed behaviors, including judgment, decision-making, problem-solving, and inhibitory control. Robust executive function is essential for successfully completing complex tasks and solving problems.

These cognitive functions are interrelated, forming the foundation of human cognitive activities. In college students, well-functioning cognitive abilities are crucial for academic success.

### **2.3 Theoretical Mechanisms of Aerobic Exercise's Impact on Cognitive Function**

While aerobic exercise's positive effects on cognitive function have been validated by numerous studies, the specific mechanisms remain partially understood. Current theories include:

**Neurophysiological Mechanisms:** Aerobic exercise increases blood flow and oxygen supply to the brain, enhancing the activity of specific regions, such as the hippocampus, which is vital for memory and learning. It also improves neural connectivity, boosting information processing efficiency.

**Neuroplasticity:** Aerobic exercise promotes neurogenesis and synaptic plasticity, enhancing neurons' capacity to store and process information. This is partly due to increased secretion of brain-derived neurotrophic factor (BDNF), a protein crucial for neuron growth and connectivity, pivotal for cognitive function improvement.

**Hormonal Regulation:** Aerobic exercise adjusts levels of various hormones, such as cortisol, norepinephrine, and dopamine, which play essential roles in regulating mood, stress response, and cognitive function. Moderate aerobic exercise can lower cortisol and

increase dopamine levels, improving mood and cognitive functions.

**Psychological Adjustment:** Aerobic exercise can enhance emotional states, reduce anxiety and depression rates, and improve mental health. Positive emotional states are fundamental for optimal cognitive function, indirectly enhancing attention, memory, and executive function.

These theoretical mechanisms collectively explain how aerobic exercise impacts cognitive functions, aiding in understanding the specific effects and operational methods of different aerobic exercise intensities in enhancing college students' cognitive functions.

### **3. Impact of Low-Intensity Aerobic Exercise on College Students' Cognitive Function**

#### **3.1 Definition and Standards of Low-Intensity Aerobic Exercise**

Low-intensity aerobic exercise refers to activities performed at a heart rate between 50%-60% of maximum. These exercises are relatively easy, causing minimal physical fatigue, and are suitable for prolonged durations. Typical examples include slow jogging, leisurely cycling, and casual walking, which are common among college students due to their ease of execution and lack of need for special equipment or venues. Additionally, low-intensity aerobic exercises do not require strong motivation or willpower, making them more likely to be accepted and sustained by a broad student population.

#### **3.2 Impact on Attention**

Several studies have explored the effects of low-intensity aerobic exercise on attention. Some research suggests that its benefits for attention are limited and vary by individual differences and frequency of exercise. For instance, Schneider et al. (2009) found that low-intensity walking could slightly improve selective attention in the short term but with minimal significance. Compared to high or moderate-intensity aerobic exercises, low-intensity exercises have weaker effects on complex attention tasks.

#### **3.3 Impact on Memory**

The impact of low-intensity aerobic exercise on memory is also varied. Some scholars believe it has positive effects on short-term and

working memory. For example, a study showed that daily 30-minute jogging for 8 weeks significantly improved working memory in a group of students compared to a control group (Hillman et al., 2008). However, these memory enhancements may quickly diminish once exercise stops, highlighting the importance of exercise consistency. However, in another study, it was found that there was no significant improvement in working memory after a one-time dose of low-intensity aerobic exercise (Yamazaki, Y et al., 2018), which indirectly suggests that periodic low-intensity aerobic exercise may have an impact on memory performance.

#### **3.4 Impact on Executive Function**

Research on the impact of low-intensity aerobic exercise on executive function is limited. Some studies suggest positive effects in areas like task switching and inhibitory control. However, compared to moderate and high-intensity exercises, low-intensity aerobic exercise has weaker effects on the efficiency of complex executive tasks. For instance, Tomporowski (2003) noted improvements in cognitive flexibility tests among students who regularly jogged lightly but no significant advantages in higher-level executive functions like decision-making and problem-solving.

### **4. Impact of Moderate-Intensity Aerobic Exercise on College Students' Cognitive Function**

#### **4.1 Definition and Standards of Moderate-Intensity Aerobic Exercise**

Moderate-intensity aerobic exercise involves activities at a heart rate between 60%-70% of maximum. These exercises effectively enhance cardiovascular fitness with minimal physical strain. Examples include brisk walking, rhythmic running, and skipping. Compared to low-intensity exercises, moderate-intensity exercises consume more energy and typically require higher motivation and willpower, thus having more pronounced effects on cognitive functions.

#### **4.2 Impact on Attention**

Research indicates that moderate-intensity aerobic exercise significantly improves attention compared to low and high-intensity exercises. Bosch et al. (2016) found that 12

weeks of moderate-intensity running training significantly enhanced sustained and selective attention. This type of exercise also positively affects attention allocation and task-switching abilities, crucial for multitasking and complex learning tasks among college students. Yue Huiling (2022) proposed that one-time moderate-intensity aerobic exercise will improve the attention distribution, attention span, attention stability, and attention transfer of college students, which also indicates that the attention ability of college students will be significantly improved after moderate-intensity exercise.

#### **4.3 Impact on Memory**

Moderate-intensity aerobic exercise also shows significant benefits for memory. Erickson et al. (2011) demonstrated that students engaging in this type of exercise showed significant improvements in semantic and working memory. This is likely due to stimulated neurogenesis and synaptic plasticity in the hippocampus, enhanced secretion of brain-derived neurotrophic factor (BDNF), and improved cognitive function, aligning with neurophysiological mechanisms. Thomas et al. (2015) used a programmed motor memory task to study the effect of acute aerobic exercise at different intensities on memory performance, and found that the retention of memory information in the high-intensity group was better than that in the low-moderate-intensity group within 1-7 days after exercise, once again proving the existence of the intensity dose effect. Li et al. (2014) found that aerobic exercise could have a positive effect on working memory by using the N-back test to measure working memory, and the performance was different from that of resistance exercise.

#### **4.4 Impact on Executive Function**

Moderate-intensity aerobic exercise has been widely validated for improving executive function. Hill et al. (2014) showed that 8 weeks of moderate-intensity running training significantly improved decision-making, planning, and problem-solving among college students. This improvement is attributed to enhanced functional connectivity in the prefrontal cortex and improved processing efficiency of executive functions. Additionally, this type of exercise aids in emotional

regulation, reducing anxiety and stress, which supports the effective execution of executive functions. Li et al. (2014) used power bicycles to study the impact of short-term and moderate-intensity aerobic exercise on the executive function of college students, and found that after short-term moderate-intensity aerobic exercise, the memory refresh ability was significantly improved in a short period of time, especially when the cognitive task load was high. In terms of inhibition of dominant response function, the accuracy rate increased after short-term aerobic exercise, indicating that the participants' ability to inhibit impulses was enhanced after exercise. The More-odd shifting task was used to study the effect on executive function, and the data analysis showed that the participants' accuracy and response scores improved after exercise, indicating that short-term aerobic exercise could promote the improvement of executive function. This increase may be due to an individual's increased level of arousal after moderate-intensity aerobic exercise.

### **5. Impact of High-Intensity Aerobic Exercise on College Students' Cognitive Function**

#### **5.1 Definition and Standards of High-Intensity Aerobic Exercise**

High-intensity aerobic exercise involves activities at a heart rate above 70% of maximum. These exercises demand significant physical exertion and often result in considerable fatigue. Common forms include fast running, high-speed cycling, and high-intensity interval training (HIIT). High-intensity exercises consume substantial energy and significantly enhance cardiovascular function but require adequate physical conditioning and experience.

#### **5.2 Impact on Attention**

The impact of high-intensity aerobic exercise on attention is complex. Some studies show temporary improvements in attention post-exercise. However, these improvements are often short-lived. Pontifex et al. (2012) found that high-intensity interval training initially improved attention task performance but gradually diminished with increased physical fatigue, possibly due to stress responses and recovery mechanisms.

### **5.3 Impact on Memory**

High-intensity aerobic exercise has dual effects on memory. Blesser (2014) found that short-term and working memory might improve briefly after high-intensity exercise, particularly within 30 minutes, likely due to increased neurotransmitter release and temporary increases in brain region blood flow. However, frequent and excessive high-intensity exercise can lead to cognitive fatigue and increased stress, negatively affecting long-term memory. Therefore, controlling intensity and frequency is crucial to avoid adverse effects on memory.

Eich and Metcalfe (2009) found that high-intensity exercise impaired the performance of memory tasks, but this study was not followed up, and Etnier et al. (2016) showed that high-intensity acute aerobic exercise was more effective than moderate-intensity and low-intensity acute aerobic exercise in improving recall performance within 24 hours after exercise.

### **5.4 Impact on Executive Function**

The effects of high-intensity aerobic exercise on executive function are varied. Some studies suggest improvements in decision-making speed and reaction sensitivity. For example, Chang et al. (2013) showed that high-intensity interval training significantly improved reaction time and action planning. However, excessive intensity and training loads can lead to cognitive fatigue and accumulated stress, potentially reducing executive function. Svensson (2015) noted that prolonged high-intensity exercise might negatively affect emotional regulation and stress management, impacting the stability and performance of executive functions.

Wang, CC et al. (2013) showed that most of the executive function performance in the high-intensity exercise group was impaired, while the performance of the low-intensity and moderate-intensity groups remained similar, and the findings also showed that the transient frontal lobe ptosis occurred during high-intensity exercise, which affected the executive function performance.

## **6. Limitations of Existing Research and Future Directions**

### **6.1 Sample Size and Methodological Limitations**

Current studies often suffer from small sample sizes, limiting the generalizability and extrapolation of findings. Additionally, the heterogeneity in experimental methods and measurement tools across studies creates inconsistencies and challenges in comparison. Future research should aim to increase sample sizes to enhance representativeness and adopt standardized experimental methods and measurement instruments to improve the comparability and reliability of results.

### **6.2 Comparability Issues**

Variations in experimental design, sample selection, exercise intervention methods, and cognitive function measurement tools across studies lead to comparability issues. Some studies utilize short-term interventions (e.g., exercise training over weeks), while others focus on long-term habits (e.g., exercise over months or years). Additionally, cognitive function assessments vary, with some studies using standardized psychological tests and others relying on self-reports or behavioral observations. These differences hinder direct comparison. Future studies should aim for standardized designs and consistent intervention and measurement methods to increase comparability.

### **6.3 Insufficient Long-Term and Mechanistic Research**

Most current studies focus on short-term effects of aerobic exercise on cognitive function, with relatively few exploring long-term impacts. It remains unclear whether long-term aerobic exercise can continuously improve cognitive function or if there is a "fatigue effect." Moreover, despite various proposed theoretical mechanisms explaining aerobic exercise's impact on cognitive function, the specific pathways and interactions are not well understood. Future research should emphasize long-term follow-up studies and utilize neuroimaging and molecular biology techniques to elucidate the mechanisms of action.

### **6.4 Recommendations for Future Research**

Future research should aim for the following improvements and expansions:  
Increase Sample Size and Diversity: Include

larger and more diverse samples covering different genders, ages, cultural backgrounds, and health statuses to enhance the generalizability and representativeness of findings.

**Standardize Research Design:** Use uniform experimental designs and measurement tools to ensure comparability across studies, particularly in exercise intervention frequency, intensity, and duration.

**Conduct Long-Term Studies:** Perform long-term follow-up studies to investigate the persistent effects of aerobic exercise on cognitive function and evaluate its sustainability and stability.

**Interdisciplinary Research:** Integrate methods from neuroscience, psychology, and exercise physiology to deeply explore the mechanisms of aerobic exercise on cognitive function, revealing its neurophysiological and molecular bases.

**Personalized Intervention Research:** Consider individual differences to explore varying responses to aerobic exercise and develop personalized exercise intervention programs to maximize cognitive function improvement.

## **7. Conclusion**

This review examines the effects of different intensities of aerobic exercise on cognitive functions in college students. Findings suggest that low-intensity aerobic exercise has limited improvements on attention, memory, and executive functions but is easy to adhere to and implement, making it suitable as part of a healthy lifestyle. Moderate-intensity aerobic exercise significantly enhances attention, memory, and executive functions, serving as the primary intervention for cognitive function improvement. High-intensity aerobic exercise shows short-term benefits for attention and memory, but prolonged high-intensity exercise may lead to cognitive fatigue and stress accumulation, negatively impacting executive functions.

The study's findings offer theoretical and practical insights. Theoretically, it supports the positive impact of aerobic exercise on cognitive functions and proposes various mechanisms, providing a foundation for future research. Practically, it offers specific exercise intervention recommendations for enhancing cognitive functions in college students. Educators and mental health professionals can

use these insights to develop scientifically sound exercise interventions to help students improve their cognitive functions, academic performance, and quality of life.

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