

Original article

Acute exercise is associated with specific executive functions in college students with ADHD: A preliminary study

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Abstract

Purpose: The relationship between acute exercise and executive functions in college students with attention deficit hyperactivity disorder (ADHD) has not been clearly established. The purpose of this preliminary study was to examine the difference in cognitive performance between college students with and without ADHD and to explore the effects of acute exercise on multiple aspects of executive functions and on serum brain derived neurotrophic factor (BDNF).

Methods: College students (normal: $n = 10$; ADHD: $n = 10$) performed the Stroop Test, Trail Making Test, and Digit Span Test prior to and after an acute exercise intervention. Blood samples were obtained prior to the pre-test cognitive test performance and then again after exercise and prior to the post-test cognitive test performance.

Results: Students with ADHD exhibited impaired executive functions, particularly on inhibition. Additionally, while acute exercise improved all aspects of executive functions in those without ADHD, acute exercise only improved inhibitory performance for those with ADHD. Further, BDNF was not influenced by acute exercise regardless of the subjects' ADHD status.

Conclusion: These results provide preliminary evidence for exercise as a potential adjunct treatment for benefitting inhibition in college students with ADHD.

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Keywords: Cognition; Executive function; Neurotrophins; Physical activity

1. Introduction

Attention deficit hyperactivity disorder (ADHD) is characterized by developmentally inappropriate levels of inattention and/or hyperactivity that result in numerous impairments in academic, social, and occupational domains.^{1–3} Although ADHD is typically characterized as being a disorder of children, the symptoms of ADHD are also evident in adults. In fact, approximately 2%–8% of college students exhibit clinical symptoms of ADHD, which is considered the second

largest disability affecting postsecondary students, after learning disabilities.⁴ College students with ADHD are at greater risk for behavioral problems (e.g., alcohol use disorders)⁵ and psychological difficulties (e.g., depression, anxiety).⁶

Individuals with ADHD also commonly suffer from deficits in cognitive functioning, particularly executive functions. Executive function refers to higher-order cognitive processes, including self-monitoring and/or self-regulating, that are responsible for purposeful and goal-directed behaviors.⁷ Impairments of executive functions in college students have translated to poor organizational skills,^{8,9} decreased self-control,³ and increased academic struggles.⁴ Also noteworthy is that executive function is not a unitary processes, but it

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involves several distinct sub-constructs such as inhibition, task switching, and working memory,¹⁰ and the executive dysfunction resulting from ADHD is believed to be sensitive to specific sub-constructs of executive function. For instance, Willcutt et al.¹¹ concluded that although ADHD in children has been associated with impairments in all executive function tasks, the largest impairments have been observed for tasks related to inhibition, working memory, and planning. However, only a few studies have examined executive function performance for college students with ADHD. These previous studies have generally emphasized only a few specific sub-constructs and reveal mixed findings,^{12–15} thus suggesting the need for more research in this area.

Importantly, exercise may be a plausible treatment for behavioral symptoms and cognitive performance of persons with ADHD.^{16,17} Several meta-analytic reviews have demonstrated the positive influence of acute exercise on cognition.^{18–20} Specifically, acute exercise of moderate intensity for 30 min has consistently been associated with improved cognitive functions across multiple cognitive domains including basic information processing,²¹ inhibition,²² and the planning aspects of executive function.^{23,24} Recently, improved cognition induced by acute exercise has been observed in individuals with ADHD. For example, acute exercise has yielded positive effects on the inhibition and switching aspects of executive functions²⁵ along with sustained attention.²⁶ It should be noted that these studies were focused on children and it is not clear whether they extend to college-aged populations. College students with ADHD appear to be “one of the most understudied age groups with ADHD”.²⁷ Given the challenges that face college students with ADHD and the supportive extant literature for the positive relationship between exercise and cognition, research exploring the potential benefits of exercise on cognition within this population is warranted.

To be prescribed as adjuvant therapy, it is important to identify potential mechanisms underlying the effects of acute exercise on cognition in persons with ADHD. One logical area of study is neurochemicals that are both important to the profile of ADHD and sensitive to exercise. ADHD has been characterized by decreased levels of brain derived neurotrophic factor (BDNF).²⁸ As a member of the neurotrophin family, BDNF is involved in neurodevelopmental processes that are responsible for the survival and growth of neurons. BDNF also plays a role in both differentiation and survival of dopaminergic neurons, which are linked to impulse regulation, suggesting that BDNF may impact dopaminergic system dysfunctions associated with ADHD.²⁹ Recent human study has further linked genetic variations of BDNF to ADHD symptoms, reflecting the involvement of BDNF in the pathogenesis of ADHD.³⁰ Notably, BDNF concentrations increase as a result of acute exercise³¹ and this effect has been positively linked to acute exercise and cognition, possibly through its role in acute mechanisms underlying synaptic plasticity.³² These findings suggest that BDNF may play a role in explaining benefits of acute exercise on cognitive functions for individuals with ADHD; however, a direct investigation

involving acute exercise, BDNF, cognition, and ADHD has not yet been conducted.

Accordingly, the purpose of the present preliminary study was threefold. Specifically, the investigation was designed to: a) identify the deficits in multiple cognitive functions, particularly executive functions, in college students with ADHD, b) test the impact of acute exercise on cognitive functions in college students with and without ADHD, and c) explore whether acute exercise influences BDNF for students with and without ADHD. It was hypothesized that the students with ADHD would exhibit multiple cognitive dysfunctions compared to their counterparts without ADHD, and that acute exercise would benefit these cognitive functions, particularly executive functions, regardless of ADHD status. Lastly, lower levels of BDNF were expected in students with ADHD before conducting acute exercise. This preliminary study will provide initial evidence relative to the potential value of acute exercise interventions as adjuncts to current ADHD treatment modalities for college students.

2. Methods

2.1. Participants

Twenty college students between the ages of 18–25 years (age: 21.75 ± 1.99 year, mean \pm SD) were recruited at Southern Illinois University Edwardsville, IL, USA. Ten students identified with ADHD and registered with the university disabilities office were recruited. To be eligible, these students provided written documentation of their ADHD diagnosis from a medical professional in which the ADHD diagnosis met standard processes based upon *Diagnostic and Statistical Manual of Mental Disorders*.¹ Nine of 10 participants with ADHD were taking stimulant medication. Students without ADHD were recruited via undergraduate classes and flyers placed around campus. Participants were excluded if they had major sensorimotor handicaps (e.g., deafness, blindness), psychosis, inadequate comprehension of the English language, or failed to demonstrate that they were healthy enough to safely complete a single bout of exercise. [Table 1](#) presents the participants' demographic characteristics. This study was approved by the university's Institutional Review Board. Participants provided informed consent and this study was approved by the university's Institutional Review Board.

2.2. Cognitive function measures

2.2.1. Stroop Test

The Stroop Test was used to measure inhibition.³³ The Stroop Test consisted of two conditions: Stroop Color and Stroop Color-Word. The Stroop Color condition consisted of 50 trials with rectangles printed in colored ink. The Stroop Color-Word condition also consisted of 50 trials, but with names of colors printed in different color ink (e.g., “BLUE” printed in green ink). For both conditions, the participant was instructed to verbally identify the color of the ink as quickly as possible. Trials in each condition were displayed on a sheet of

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