

Original article

The effect of acute exercise on cognitive performance in children with and without ADHD

Aaron T. Piepmeier^a, Chia-Hao Shih^a, Margaret Whedon^b, Lauren M. Williams^a,
Matthew E. Davis^a, David A. Henning^a, SeYun Park^a, Susan D. Calkins^b, Jennifer L. Etnier^{a,*}

^a Department of Kinesiology, University of North Carolina at Greensboro, Greensboro, NC 27412, USA

^b Department of Human Development and Family Studies, University of North Carolina at Greensboro, Greensboro, NC 27412, USA

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Abstract

Background: Attention deficit hyperactivity disorder (ADHD) is a common childhood disorder that affects approximately 11% of children in the United States. Research supports that a single session of exercise benefits cognitive performance by children, and a limited number of studies have demonstrated that these effects can also be realized by children with ADHD. The purpose of this study was to examine the effect of acute exercise on cognitive performance by children with and without ADHD.

Methods: Children with and without ADHD were asked to perform cognitive tasks on 2 days following treatment conditions that were assigned in a random, counterbalanced order. The treatment conditions consisted of a 30-min control condition on 1 day and a moderate intensity exercise condition on the other day.

Results: Exercise significantly benefited performance on all three conditions of the Stroop Task, but did not significantly affect performance on the Tower of London or the Trail Making Test.

Conclusion: children with and without ADHD realize benefits in speed of processing and inhibitory control in response to a session of acute exercise, but do not experience benefits in planning or set shifting.

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1. Introduction

From 2003 to 2011 in the United States, the estimated prevalence of 4–17 year olds diagnosed with attention deficit hyperactivity disorder (ADHD) increased from 7.8% to 11%.¹ The *Diagnostic and Statistical Manual of Mental Disorders* (DSM-V)² has classified three distinct presentations of ADHD: Predominantly Inattentive, Predominantly Hyperactive-Impulsive, and Combined (inattentive and hyperactive-impulsive). For children between 12 and 16 years old, their diagnosis into an ADHD category is dependent on

the development of multiple symptoms prior to age 12 years, and the experience of these symptoms for the past 6 months at a level where they are deemed as disruptive or inappropriate for the child's developmental level. Currently, 6.1% of children in the U.S. are taking medication to reduce ADHD symptoms. As well as producing an estimated US\$31.6 billion in costs for the U.S.,³ by definition symptoms of ADHD interfere with aspects of social, academic, and work life. The impetus for this study comes from these personal and economic burdens connected to ADHD, and the purpose is to provide further exploration into the effect of exercise on the cognitive performance of children with ADHD.

Theories as to the etiology of ADHD have been linked to neurological differences in the structure⁴ and function⁵ of the prefrontal cortex. This area of the brain is responsible for the

* Corresponding author.

E-mail address: jletnier@uncg.edu (J.L. Etnier)

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performance of a set of higher order cognitive tasks, designated as “executive function” tasks that require response inhibition, planning, working memory, updating, and task switching.^{6–9} Research has shown that individuals with ADHD perform significantly worse on neuropsychological tasks requiring executive function than do children without ADHD.^{10–13} As a result, it is important to explore interventions that may benefit executive function by children with ADHD.

There is support in the literature for the beneficial effects of acute exercise on cognitive performance,¹⁴ and specifically its effect on executive function.^{15–17} Meta-analytic research has shown that the beneficial effect of exercise on cognitive performance is especially manifested in children.^{18,19} However, there is a paucity of research exploring whether or not exercise may benefit the cognitive performance of children with ADHD. In fact, to date, there have only been a small number of studies that explored the effects of acute exercise on cognitive performance in children with ADHD.

Grassmann et al.²⁰ conducted a systematic review of articles published between 1980 and 2013 and noted that there were only three studies at that time that had explored the effect of an acute bout of exercise on the cognitive performance of children with ADHD. Of these studies, two observed significant benefits on measures of cognitive performance after participating in a 30-min bout of exercise.^{16,21} Medina et al.²¹ observed improvements in measures of vigilance and reaction time as assessed with Conners’ Continuous Performance Test-II (CCPT-II) following vigorous exercise for 30 min. Chang et al.¹⁶ observed improvements in measures of inhibition and set shifting as assessed with the Stroop Task and Wisconsin Card Sorting Task, respectively, following moderate intensity exercise for 20 min. However, neither of these studies employed a comparison group consisting of children without a diagnosis of ADHD, hence it is not clear from these studies how the effects for children with ADHD compare to those for children without ADHD.^{22–24} There are three studies in which effects of exercise were compared between children with and without ADHD.^{22–24} Craft²² tested hyperactivity as a moderator of the effects of exercise on cognitive performance. She explored the effects of short-duration vigorous exercise conditions (i.e., 0, 1, 5, 10 min) on the cognitive performance (i.e., Wechsler Intelligence Scale for Children – Revised Digit Span and Coding, Illinois Test of Psycholinguistic Abilities – Visual Sequential Memory) of children with and without a diagnosis of “hyperactivity” as determined by the Conners’ Abbreviated Teacher Rating Scale. Results indicated that children diagnosed as non-hyperactive performed better on the cognitive tasks than those diagnosed with hyperactivity supporting findings of past literature. However, neither group experienced significant changes in performance as a function of exercise. This lack of an improvement in response to exercise may have been due to the short durations of the exercise, given that Chang et al.¹⁴ reported null effects for exercise durations of 0–10 min in duration. Pontifex et al.²³ explored the effects of a 20-min bout of moderate intensity exercise on the cognitive performance of children with and without a

diagnosis of ADHD. Cognitive performance was assessed by an inhibitory control task (i.e., Flanker Task), neuroelectrical (i.e., the P3 component of event-related potential, error related negativity) measures of executive function, and academic performance measures of reading comprehension, spelling, and math (i.e., Wide Range Achievement Test, 3rd Edition). Results indicated that both groups experienced significant improvements in measures of cognitive performance (i.e., behavioral) and cognitive function (i.e., neuroelectrical) following exercise. Mahon et al.²⁴ recruited children with and without ADHD to perform the CCPT-II prior to and following 20 min of intermittent, high-intensity exercise. Children with ADHD were also invited to perform the experimental protocol on a day when they had taken their normal medication and on a day when they had abstained from their medication for 18–24 h. Results of this study indicated that exercise actually resulted in worse performance on the CCPT-II in terms of errors of omission for children with and without ADHD and in terms of reaction time for children with ADHD. Again, this failure to demonstrate benefits to cognitive performance in response to exercise may have been due to the use of a high-intensity, intermittent protocol which resulted in a total exercise session of only 10 min. Overall, the extant literature is mixed with regards to whether or not acute exercise benefits the cognitive performance of children with ADHD, but supports the hypothesis that children diagnosed with ADHD experience cognitive benefits in response to an acute bout of moderate or vigorous intensity exercise that is of sufficient duration (e.g., >20 min).

An exploration into the beneficial effects of exercise on the cognitive performance of children with ADHD is a logical line of research considering that those with ADHD have shown impaired performance on cognitive tasks requiring executive function and exercise has been shown to improve executive function performance in the general population. At this time, there is limited research that has compared the effects of acute exercise on cognitive performance between children with and without ADHD^{22–24} and only one study²³ has done this using an exercise protocol that meta-analytic evidence suggests would be expected to improve cognitive performance. However, this study²³ only included one type of executive function measure. Hence, the purpose of this study was to further our understanding of the extent to which 20-min of moderate intensity exercise impacts various aspects of executive function performance by children relative to their ADHD status.

2. Methods

2.1. Participants

Participants consisted of 32 adolescents recruited from a private K–12 school, the local community, and an ADHD clinic. Because a within-subjects design was used, differences in participants as a function of recruitment location were not analyzed. Recruiting was performed through the use of fliers and emails. In addition, on-site recruiting was used in the private K–12 school during a weekly informational assembly.

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