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Individual Differences in Lifestyle Factors and the Effects of Acute Exercise on Executive Functioning in Children and Youth with ADHD

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Abstract

Acute exercise interventions can improve executive functioning among children and youth with ADHD, however not all individuals experience the same benefit. We focused on three lifestyle factors (medication use, physical fitness, and physical activity behaviours) and their impact on the relationship between acute exercise and executive functioning. Participants completed a battery of executive functioning measures, followed by a 10-minute bout of moderate-intensity stationary biking (experimental condition), or silent reading (control condition). The same battery of assessments was re-administered immediately after the intervention and after a 10-minute delay. Overall, regardless of medication status, physical fitness level, or physical activity behaviours, an acute bout of exercise had similar effects on executive functioning outcomes. However, the pattern of data suggests that physical fitness level may influence the relationship between exercise and executive functioning. However, further research with a larger sample size is needed to unravel this issue.

Keywords

Attention Deficit Hyperactivity Disorder

Children and Youth

Acute Exercise

Executive Functioning

Inhibitory Control

Task-Switching

Working Memory

Physical Fitness

Medication

Physical Activity Behaviours

Summary for Lay Audience

Attention-Deficit Hyperactivity Disorder (ADHD) is a prevalent neurodevelopmental disorder in children and youth. Individuals with ADHD typically experience executive functioning deficits that negatively impact their working memory (the ability to hold on to and manipulate information), inhibitory control (the ability to filter out distracting information), and task-switching (the ability to switch from one task to another). Pharmacological interventions (i.e., medication) are the primary method for alleviating ADHD symptomology. Although beneficial, stimulant medications can elicit undesirable side effects and often fail to address academic challenges common to children with ADHD. Exercise interventions have been identified as a potential supplemental treatment for children and youth to help ameliorate ADHD symptomology. Research in this area has focused mainly on the impact of long-term exercise interventions (i.e., weeks or months long) or longer exercise bouts (30 minutes to an hour). There has been less work dedicated to understanding how a short bout (10 minutes) of acute (i.e., a single session) exercise may impact executive functioning in children and youth with ADHD. Further, there has been little to no research investigating how individual differences in lifestyle factors may impact a child's reactivity to acute exercise interventions. The current study focused on the role of three individual difference factors (medication status, physical fitness level, physical activity behaviours), and how they impact the relationship between acute exercise and executive functioning in children and youth with ADHD. Participants diagnosed with ADHD between the ages of 10-14 engaged in two sessions, an exercise session and a control session. During the exercise condition, participants completed a 10-minute bout of moderate-intensity stationary biking in addition to a pre-post battery of executive functioning assessments. The control condition consisted of 10-minutes of silent reading. Following a 10-minute bout of

exercise, we found that regardless of medication status, physical fitness level, or physical activity behaviours, all individuals performed similarly well on each measure of executive functioning. Despite similar performance across groups, the pattern of data suggests that physical fitness level may impact the relationship between acute exercise and executive functioning among children and youth with ADHD. However, further research with a greater sample size is needed to fully unravel this issue.

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Chapter 1: Introduction

1.1 Statement of the Problem

Attention-Deficit Hyperactivity Disorder (ADHD) is a highly common neurodevelopmental disorder among children and youth (Benzing, Chang, & Schmidt, 2018). ADHD is characterized by age-inappropriate symptoms of inattention and/or hyperactivity and impulsivity (Christiansen et al., 2019; Geladé et al., 2017). ADHD has well-documented detrimental impacts on social and academic skills as well as work-related impairments, thus creating a large social burden (Benzing, Chang, & Schmidt, 2018; Christiansen et al., 2019). Many children with ADHD also experience executive functioning deficits (Benzing, Chang, & Schmidt, 2018; Christiansen et al., 2019; Holmes et al., 2010). Executive functioning is defined as higher-order cognitive functions that are required to plan, self-regulate, and achieve goals (Benzing, Chang, & Schmidt, 2018; Schoemaker et al., 2012; Silverstein et al., 2020). Among children and youth with ADHD, the three primary aspects of executive functioning that are typically compromised include inhibitory control, working memory, and task-switching (Christiansen et al., 2019; Holmes et al., 2010). To alleviate symptomology, ADHD is most commonly treated with medication, but undesirable side effects (ie. stomach-aches, delayed growth, mood disturbances; Janssen et al., 2016; Kidwell et al., 2015) have led to substantial interest in alternative and adjunct interventions. One proposed non-pharmaceutical intervention is exercise, which is thought to positively effect executive functioning performance (Berwid & Halperin, 2012; Piepmeier et al., 2015; Pontifex et al., 2013). While exercise interventions are efficacious in enhancing executive functioning, little attention has been paid to the individual difference factors which may influence the effectiveness of exercise interventions for mitigating ADHD symptoms.

1.2 Summary of Study

Although engaging in exercise has been shown to ameliorate executive functioning deficits in children and youth with ADHD (Benzing, Chang, and Schmidt (2018); Chang et al., 2012b; Ziereis and Jansen (2015), individual differences in medication use, physical fitness level, and physical activity behaviours may influence the efficacy of exercise interventions for mitigating ADHD symptoms. Given the ubiquity of medication use among children and youth with ADHD (Hauck et al., 2017), it is important to consider its impact on the relationship between exercise and executive functioning. Further, within neurotypical populations, physical fitness level often influences the relationship between exercise interventions and executive functioning (Ludyga et al., 2016). This relationship has not been investigated in children and youth with ADHD. In addition, no work has investigated the impact of individual differences in physical activity behaviours among neurotypical or ADHD populations, despite the potential for this factor to impact the efficacy of exercise interventions. The following introduction will describe the relationship between ADHD and executive functioning, non-pharmaceutical treatment options for ADHD, the current research on the impact of exercise interventions on executive functioning, and the role of individual difference factors and their impact on the relationship between exercise interventions and executive functioning performance.

1.3 Executive Functioning and its Role in ADHD

Executive functioning refers to processes that facilitate deliberate goal-directed behaviour and includes attention, reasoning, working memory, planning, and inhibiting (Biederman et al., 2004; Craig et al., 2016; Silverstein et al., 2020). Children and youth with ADHD often struggle academically, which has been linked to deficits in executive functioning and often leads to difficulties completing tasks involving complex behaviours (Anastopolous et al., 2011;

Biederman et al., 2004). These deficits in executive functioning are thought to be caused in part by prefrontal cortex (PFC) dysfunction (Arnsten & Li, 2005). More specifically, networks in the PFC (i.e., frontostriatal and frontoparietal) that are highly related to processes of executive functioning are often underactive in individuals with ADHD (Silverstein et al., 2020). As a result of executive functioning deficits, children with ADHD are at an increased risk for academic difficulties including grade retention, learning disabilities, and overall lower academic achievement (Biederman et al., 2012). There are three distinct executive functions that are compromised in individuals with ADHD: inhibitory control, task-switching, and working memory (Benzing, Chang, & Schmidt, 2018). Given that these three executive functions are strong predictors of academic success, deficits in executive functions are a window for potential academic struggles for children and youth with ADHD.

1.3.1 Inhibitory Control

Inhibitory control is an essential component that is required to successfully suppress preplanned dominant, automatic, or habitual responses to a particular stimulus (Kofler et al., 2019; Munakata et al., 2011). Impulsivity, a lack of inhibitory control, involves the inability to filter out distracting or useless information and refrain from engaging in inappropriate behaviours (Slusarek et al., 2001). To be successful in a classroom setting, a child must have the capacity to resist automatic or reactive responses and respond to instructions and task requirements in a reflective and flexible way (Raver & Blair, 2016). Given their vulnerability to disruption and distraction, children with ADHD may also struggle to refrain from engaging in inappropriate behaviour which may lead to detriments in social functioning.

1.3.2 Task-Switching

Task-switching requires the ability to shift attention from one task to another (Kofler et al., 2019). In order for an individual to effectively switch between tasks, they must ignore a previously active task-set in order to favour the new task-set (King et al., 2007). The ability to focus and shift attention plays an important role in a child's capacity to solve problems, specifically in the context of play and learning (Blair & Razza, 2007). In an everchanging classroom, children with ADHD may have difficulty effectively switching from one task or lesson to another which could ultimately lead to slower learning. Additionally, task-switching requires flexibility and adaptability and is essential for a host of cognitively demanding tasks (Clark et al., 2010). Thus, deficits in task-switching performance may lead children and youth with ADHD to have difficulty completing complex tasks.

1.3.3 Working Memory

Finally, working memory involves the temporary storage and manipulation of information in the short-term (Kofler et al., 2019). Working memory requires an individual to briefly hold information in their short-term memory, and later use it to complete a task, such as remembering a particular set of numbers to be recalled backwards (Bowler & Lezak, 2015). Working memory plays a significant role in goal-directed behaviour as well as higher-order problem solving (Raver & Blair, 2016). Poor working memory ability can also lead to behavioural and attentional difficulties which in turn engenders social functioning problems and challenges at school (Chiang & Gau, 2014; Hilton et al., 2017; McQuade et al., 2013). Taken together, these executive functions are essential for an individual to successfully engage in an environment that is everchanging and are fundamental for academic and life success (Cotrena et al., 2016).

1.4 Pharmacological Approaches to ADHD

The most common treatment for individuals with ADHD is pharmacological intervention including stimulant and non-stimulant pharmacotherapy (Christiansen et al., 2019). Stimulant medications such as methylphenidate and amphetamines are most frequently prescribed (Bachmaan et al., 2017; Shier et al., 2013). As previously mentioned, deficits in executive functioning are often associated with PFC dysfunction (Arnsten & Li, 2005). The executive functions that are facilitated by the PFC are highly sensitive to changes in neurotransmitters, specifically norepinephrine and dopamine (Mehta et al., 2019). As such, stimulant medications work to facilitate the release of norepinephrine and dopamine within the PFC, which promotes PFC functioning and therefore enhances executive functioning (Shier et al., 2013; Xing, Li, & Gao, 2016).

Although stimulant medication can improve attention, motivation, and concentration in children with ADHD, there is still debate around the efficacy of stimulants for improving academic performance and classroom behaviour (Carlson & Kruer, 2007; Kortekaas-Rijlaarsdam et al., 2019; Hale et al., 2011; Prasad et al., 2013). Additionally, approximately 30% of individuals do not respond favourably to medication or experience some form of adverse effects (i.e., sleep disturbances, headaches, appetite suppression, and mood disturbances; Janssen et al., 2016; Kidwell et al., 2015; Shier et al., 2013). Physical repercussions of medication are also seen in children with ADHD and can include delayed growth, headaches, stomach-aches, and increased heart rate (Kidwell et al., 2015; Zachor et al., 2006). Thus, medication can have negative side effects that impair a variety of aspects of an individual's quality of life. Further, stimulant medications also fail to treat the psycho-emotional disturbances that are often comorbid with ADHD (Cormier, 2008). This is especially important given that approximately

25% of children with ADHD meet the criteria for depression and anxiety disorders (Root & Resnick, 2003; Seymour & Miller, 2017). Given these limitations, there has been a push for determining alternative, supplemental treatment options that are safe and effective. One of these potential adjunct treatment options is exercise.

1.5 Cognitive Benefits of Exercise

In neurotypical populations, exercise has been shown to enhance executive functioning, specifically through improved attention, working memory, cognitive flexibility, and decision making (Howie et al., 2015; Mahar, 2011; Pesce et al., 2009). Growing literature suggests that exercise impacts brain function and structure and provides an avenue for neural and cognitive development to be promoted in both the short- and long-term (Berwid & Halperin, 2012). Neuroimaging studies involving children have started to reveal the mechanisms by which habitual exercise can improve executive functioning. For example, individuals who are more physically fit have greater hippocampal volume, which is a critical area of the brain involved in the formation of new memories (Donnelly et al., 2016; Erickson et al., 2015). More physically fit children and youth also show more efficient patterns of brain activity and have greater white matter integrity within neural structures that are crucial for neural communication (Donnelly et al., 2016; Erickson et al., 2015). Following an acute bout of exercise, individuals also demonstrate increased cerebral blood flow in the PFC, which is essential for optimal neural functioning (Giles et al., 2014; Tam, 2014). Indeed, improvements in executive functioning within the PFC have been associated with increased cerebral blood flow, suggesting this increase facilitates cognitive processing speed during highly demanding cognitive tasks (Tam, 2014). Acute exercise may also increase levels of neurotransmitters, specifically dopamine, norepinephrine, and serotonin (Loprinzi et al., 2013). The release of both dopamine and norepinephrine lead to heightened cognitive performance and information processing, while increased levels of serotonin can work to enhance mood and attention (Ng et al., 2017). Similar to pharmacotherapy, exercise also appears to alleviate ADHD symptomology by exerting physiological effects that increase neurotransmitters such as dopamine and norepinephrine (Ng et al., 2017). As ADHD is often associated with deficits in executive functioning and weakened regulation of the PFC, exercise interventions may be an effective avenue for helping to combat some of these deficits and improve executive functioning in children and youth with ADHD.

1.6 Exercise Interventions for Individuals with ADHD

Multiple studies have demonstrated that routine, long-term exercise interventions can lead to significant improvements in executive functioning among those with ADHD. For example, Ziereis and Jansen (2015) found that a 12-week exercise intervention for children with ADHD (n = 43; 7-12 years old) significantly improved working memory on a variety of tasks including digit span, letter-number-sequencing, and Corsi block tapping. Similarly, a 10-week exercise intervention for children with ADHD (n = 21; 7-12 years old), with children participating three times a week for 45 minutes in various moderate-to-vigorous exercise (i.e., basketball, soccer, exercise stations, and tag or ball games) produced significant improvements on tasks assessing attention and response inhibition, when compared to controls who did not participate in the exercise intervention (Verret et al., 2012). Further, Pan and colleagues (2019) revealed that children with ADHD (n = 30; 7-12 years old), who participated in 70-minutes of table tennis twice per week for 12 weeks had significantly higher performance on measures of attention, inhibition, and working memory, compared to controls who did not participate in the intervention.

While routine and long-term exercise opportunities are important for any population, adherence to programs and the significant time-commitment required poses a challenge to this long-term method as an intervention for children and youth with ADHD. As a result, researchers have sought to investigate the benefits of single session, short bouts of exercise interventions and their impact on lessening ADHD symptomology. Benzing, Chang, and Schmidt (2018) demonstrated that a 15-minute bout of exercise involving exergaming (i.e., a combination of exercising and gaming), improved inhibitory control and task-switching performance for children with ADHD (*n* = 46; 8-12 years old),. In a study by Chang and colleagues (2012b), children with ADHD (*n* = 40; 8-15 years old), were randomly assigned to a control or exercise condition consisting of 30-minutes of moderate intensity running on a treadmill. Their results showed that individuals in the exercise condition performed better on a measure of inhibitory control (Stroop Test) and demonstrated enhanced working memory performance (on the Wisconsin Card Sorting Test), when compared to controls who did not participate in the exercise component. Similar findings were revealed by Piepmeier and colleagues (2015) who had children with and without ADHD (*n* = 32; M_{age} = 10.75), complete a 30-minute exercise protocol (cycling on a stationary bike), followed by a battery of executive functioning tests. Their results indicated that participants with and without ADHD demonstrated significant improvements in inhibitory control following the acute exercise bout. Additionally, Medina and colleagues (2010) found that children's (*n* = 25; 7-15 years old), ADHD symptomology was significantly reduced following 30 minutes of high-intensity treadmill running. Taken together, evidence suggests that exercise, in both acute and chronic forms, is a potential supplemental treatment for executive functioning deficits associated with ADHD. However, there has been little to no research examining how children with ADHD may differentially respond to exercise interventions as a function of individual difference factors. The current study aimed to investigate how individual difference factors may influence the efficacy of exercise interventions for children and youth with ADHD.

1.7 The Impact of Individual Difference Factors

While there is evidence to suggest that short-term and long-term engagement in exercise can improve executive functioning among children and youth with ADHD, not all individuals will reap those benefits to the same degree. Some preliminary research proposes that certain factors may impact an individual's reactivity to exercise interventions (Ludyga et al., 2016). The current study examined how three important lifestyle factors (medication use, physical fitness level, and physical activity behaviours) impacted the effectiveness of an acute bout of exercise for improving executive functioning in children and youth with ADHD.

1.7.1 Individual Differences in Medication Use and its Impact on Exercise Interventions

Given that medication is highly utilized for decreasing ADHD symptomology, it is important to consider the impact that medication status may have on an individual's reactivity to an acute exercise intervention. Within Ontario, approximately 70% of children and youth below the age of 24 are prescribed medication for ADHD (Hauck et al., 2017). Thus, it is important to consider the potential impact that medication could have on the efficacy of acute exercise for executive functioning. Limited studies have focused on how medication status might influence the relationship between exercise and executive functioning among children and youth with ADHD. However, Medina and colleagues (2010) revealed that children's attentional deficits were minimized through exercise regardless of their medication use. The study involved children with ADHD who were divided between users and non-users of methylphenidate, a common stimulant medication prescribed to individuals with ADHD (Medina et al., 2010; Shier et al., 2013). Participants completed a 30-minute bout of high-intensity running on a treadmill which was followed by a measure of sustained attention (Conner's Continuous Performance Test-II). Sustained attention was not affected by stimulant medication use and attentional deficits were minimized through exercise irrespective of pharmacological treatment (Medina et al., 2010).

Additionally, a study conducted by Chang and colleagues (2012b) controlled for medication use among children with ADHD and found no differences in how participants responded to the exercise intervention, suggesting that individuals can reap similar benefits of exercise on executive functioning regardless of their medication status. A review by Christiansen and colleagues (2019) did not discuss the potential interaction between medication use and exercise. They explicitly noted that subgroup analyses have generally not revealed medication usage to moderate the effects of exercise of cognitive performance (Christiansen et al., 2019). These studies suggest that exercise enhances executive functioning regardless of whether an individual is on medication or not. These results are promising as they suggest that individuals with ADHD can reap the benefits of exercise on their executive functioning regardless of their medication use. However, there is still a need for more research to support this claim.

1.7.2 Individual Differences in Physical Fitness and its Impact on Exercise Interventions

Previous research with typically developing populations suggests that one's level of physical fitness influences how an exercise intervention impacts executive functioning performance (Chang et al., 2015; Hogan et al., 2013; Ludyga et al., 2016). While this relationship has been studied in neurotypical populations, there has been no research examining how physical fitness level may influence the relationship between exercise and executive functioning among children and youth with ADHD. The exercise-induced benefits to one's executive functioning have been investigated in different age and aerobic-fitness subgroups

(Ludyga et al., 2016). Within the literature, there appears to be three trends concerning how physical fitness impacts the relationship between exercise and executive functioning.

The first trend asserts that individuals who are more physically fit experience greater exercise-induced benefits (Chang et al., 2015). Prior work has split participants into either a high-fitness or a low-fitness group based on participants' level of cardiovascular fitness (Chang et al., 2015). In order to measure cognitive effects, the Stroop Test was used as a measure of processing speed, inhibition, and sustained attention (Chang et al., 2015). All participants demonstrated improved performance on the Stroop Test following 20-minutes of stationary biking, however individuals in the high-fitness group experienced a significantly greater benefit. These increased benefits for high-fit individuals may be facilitated by existing brain resources (Chang et al., 2015). Specifically, individuals with higher physical fitness levels may have increased default mode network (DMN) connectivity, a network of highly connected brain regions, which in turn provides a pathway for improved executive functioning (Voss et al., 2010). Adults who are more physically fit also have greater neuronal plasticity, allowing the brain to change in response to alterations in the environment and to form new neural connections which is important for learning (Colcombe et al., 2006; Erikson et al., 2009; Prakash et al., 2011). While the results of Chang et al.'s study are promising, this effect was only investigated in a population consisting of neurotypical male participants between the ages of 60-70 years old (Chang et al., 2015). Thus, individual differences in physical fitness levels among children and youth with ADHD should also be examined to better identify those that may benefit the most from exercise interventions.

The second trend states that low-fit individuals experience greater exercise-induced benefits to their executive functioning. Evidence for this trend comes from a study involving adolescents between the ages of 13-14 who were divided into either a high-fit or low-fit group using a continuous-graded maximal exercise test (Hogan et al., 2013). Researchers found that individuals in the high-fit condition demonstrated greater inhibitory control during the resting (control) condition. However, the group differences were less pronounced following a 20-minute bout of stationary biking, suggesting that acute exercise may improve inhibitory control efficiency particularly for less fit individuals (Hogan et al., 2013). Based on results from their EEG analysis, researchers noted that the low-fit group appeared to be exerting a greater amount of cognitive effort compared to the high-fit group during the control condition. This suggests that higher-fit individuals may facilitate greater cortical efficiency when completing cognitive tasks. The group differences in cortical efficiency, however, were less pronounced following a bout of acute exercise. Taken together, an acute bout of exercise may level the effects of physical fitness on inhibitory control.

Finally, the third trend asserts that the effect of exercise on executive functioning does not differ between low, average, or high-fit individuals (Ludyga et al., 2016). A meta-analysis was conducted within a variety of age subgroups to examine the potential moderating effect of physical fitness level on the exercise-induced benefits for executive functioning (Ludyga et al., 2016). Subgroup analyses revealed no differences on executive functioning performance following a bout of stationary biking, between low-fit, average-fit, or high-fit participants. The variability in results across studies could be due to the timing in which the cognitive task was administered relative to the exercise component (Ludyga et al., 2016). Some research suggests that physical fitness level only moderates the effect of exercise on executive functioning when the task is administered *during* the exercise component (Chang et al., 2012b). It is possible that high-fit fit individuals require less cortical resources during an exercise task, allowing them to allocate extra attentional resources towards cognitive tasks (Ludyga, Gronwald, & Hottenrott, 2016). When executive functioning performance is assessed after an exercise intervention, the higher-fit participants may no longer benefit from this advantage. Overall, these findings are particularly interesting as they suggest that acute exercise enhances executive functioning regardless of an individual's fitness level.

While these results have not been demonstrated within an ADHD population, they provide insight into the possible ways that physical fitness level could impact executive functioning performance following an exercise intervention. Given that exercise has been highlighted as an effective adjunct treatment option for individuals with ADHD (Howie et al., 2015; Pontifex et al., 2013), it is important to gain a better understanding of how lifestyle factors, such as physical fitness level, could influence an individual's reactivity to an acute exercise intervention.

1.7.3 Individual Differences in Physical Activity Behaviour and its Impact on Exercise Interventions

A thorough search of the literature found limited research investigating how physical activity behaviours impact responsiveness to exercise interventions. Physical activity behaviours include the frequency and type of physical activity that an individual generally participates in on a weekly basis. Examples of physical activity behaviours include walking, running, dancing, biking, team sports, skating, etc. One possibility for the lack of research focusing on individual differences in physical activity behaviours could be that these behaviours are often confounded with physical fitness level. For example, greater levels of fitness may indicate greater participation in physical activity behaviours. However, the current study differentiated between physical fitness and physical activity behaviours in order to gain a better understanding of the differences between these two related but separate constructs.

1.8 Theoretical Framework

The current study utilized an individual difference model where three lifestyle factors (medication status, physical fitness level, physical activity behaviour) were considered when evaluating the impact of an acute exercise intervention on executive functioning. The key theoretical framework that underlies the current study is the *Aptitude-Treatment Interaction*, a framework designed to take individual differences into account when evaluating the efficacy of a particular treatment or intervention (Snow, 1991). Within this framework, aptitude is defined as any measurable characteristic that is hypothesized to influence an individuals' outcome following a treatment or intervention (Snow, 1991). A great deal of research focuses on group differences and group outcomes, however we know that individuals with ADHD are not a homogenous group. Thus, the current study aimed to better understand how the individual difference factors of medication use, physical fitness level, and physical activity behaviours, may affect an individuals' responsiveness to an acute exercise intervention. This information has the potential to identify and target individuals who may experience the greatest benefit from exercise interventions.

1.9 Current Thesis

The current thesis investigated the impact of individual differences in medication status, physical fitness, and physical activity behaviours on the efficacy of an acute exercise bout on executive functioning in children and youth with ADHD. Further, the research also aimed to provide additional evidence for the efficacy of acute exercise interventions for children and youth with ADHD. In the current study, participants completed a battery of executive functioning measures before and after participating in an acute exercise intervention (10 minutes of moderate-intensity biking). Approximately one week after participating in the experimental condition, participants returned and completed the same procedure, but engaged in 10-minutes of silent reading in lieu of the exercise component (see Appendix A for a flow chart of the study procedure). Participants were then split into binary groups based on their medication status, physical fitness level, and physical activity behaviours for analyses.

1.10 Research Questions and Hypotheses

1) *How do individual differences in medication use influence the effect of an acute bout of exercise on executive functioning in children and youth with ADHD?*

We predicted that regardless of medication status, all individuals would demonstrate improved performance on tasks of executive functioning (inhibitory control, task-switching, and working memory) following an acute exercise bout. This effect has been examined in previous research evaluating the role of medication use on executive functioning performance (Chang et al., 2012b; Medina et al., 2010).

2) *How do individual differences in physical fitness levels influence the effect of an acute bout of exercise on executive functioning in children and youth with ADHD?*

Research in neurotypical populations investigating the impact of physical fitness level on the relationship between exercise interventions and executive functioning has been inconsistent. Some researchers have suggested that all individuals can benefit from exercise interventions regardless of their physical fitness level (Ludyga et al., 2016). On the other hand, some researchers have demonstrated greater executive functioning benefits for higher-fit individuals (Chang et al., 2015) and lower-fit individuals (Hogan et al., 2013). Therefore, our hypothesis remained mostly exploratory given the conflicting evidence within the literature.

3) *How do individual differences in physical activity behaviours influence the effect of an acute bout of exercise on executive functioning in children and youth with ADHD?*

Our hypothesis for this question also remains largely exploratory given that there is little to no research focusing on physical activity behaviours as an individual difference factor.

Chapter 2: Methodology

2.1 Participants

Our sample included 16 children and youth with ADHD. A sample size calculation was performed using G*Power with medium to large effect size Cohens $d = 0.6\text{-}1$, power of 0.95, alpha of 0.05, with primary outcome variable as change in executive functioning, indicating 30 participants were needed. Our goal was to recruit 30 participants, but we were only able to recruit 16 due to COVID-19. The study was reviewed and approved by the Western University Health Science Research Ethics Board. Data collection took place from May 2019 to March 2020 and was terminated due to COVID-related data collection restrictions. Participants were recruited through The Child and Youth Development Clinic and The Mary J. Wright Research and Education Centre at Merrymount, both of which are affiliated with Western University. Participants were aged 10-14 ($M = 11.38$, $SD = 1.5$) and there were 12 males and 4 females, reflecting the common gender discrepancy in ADHD diagnoses (Nøvik et al., 2006). The inclusion criteria included children and youth between the ages of 10-14 with a diagnosis of ADHD. Parental verification was used to confirm the presence of an ADHD diagnosis. One participant without a formal diagnosis of ADHD was included in the study as they had been prescribed ADHD medication by their physician and were currently taking the medication, however they had not yet received an official diagnosis. Exclusion criteria included non-English speakers, children who were not fully literate, those who had any neurological or developmental exceptionalities outside of ADHD, and individuals who were colour-blind (as it would interfere with performance on the Stroop Test). This section will describe the measures of executive functioning that were used, the demographic information that was collected, and the full study procedure.

2.2 Materials: Assessments of Executive Functioning

2.2.1 Stroop Test (Stroop, 1935)

The Stroop Test is a non-invasive and reliable measure of inhibitory control. The task requires the inhibition of automatic word reading and is often used to assess inhibitory control in children and youth with ADHD (Scarpina & Tagini, 2017). The incongruent version of the Stroop Test was used (Appendix B). The task required the participant to name a list of colours, where the colour that the word was printed in differed from the actual colour word. For example, the word 'blue' may have been printed in the colour yellow, but the participant was required to say 'yellow' as opposed to the actual word, blue. The participant completed this trial for 150 seconds. Participants were instructed to read through the list of words as quickly as possible, without making any errors. The participant's response time was recorded using a stopwatch, and errors, words completed, and reaction time were all recorded and used to determine their score.

2.2.2 Trail Making Task (Reitan, 1955)

The Trail Making Task (TMT) is a reliable and valid measure of executive functioning in children and youth. In the current study, the TMT-B was used as a measure of cognitive flexibility and task-switching (Appendix C; Reitan, 1955). The task required participants to draw one sequential line connecting 25 encircled numbers and letters that were randomly distributed throughout a piece of paper. Participants were instructed to alternate between connecting numbers and letters (i.e., 1, A, 2, B, 3, C, etc.). The score was derived based on the amount of time the participant took to complete the task (as recorded by a stopwatch).

2.2.3 Working Memory Task

Participants' working memory was assessed using the Reverse Memory (RM) Subscale of the Leiter-3 International Performance Scale. The RM subscale is a complex non-verbal task that requires the participant to mentally store and manipulate information and is a valid and reliable indicator of working memory capacity (Roid & Koch, 2017). The Leiter-3 is recognized as a standard tool for assessing children with disabilities in both research and clinical settings and has been validated with ADHD populations (Farmer, 2013; Roid & Koch, 2013). Picture matrices that varied in size (2x2; 2x6) were placed in front of the participant (Appendix D). The experimenter pointed to a series of pictures in a particular sequence and the participant was instructed to then point to the images in the reverse order of what was presented to them. The task became increasingly difficult as the sequence of pictures to be recalled increased from 2 to 9. After making six errors, the final number of correctly recalled pictures was recorded as the participant's working memory span.

2.3 Materials: Assessments of ADHD Presentation

2.3.1 Vanderbilt Parent Rating Scale (VADPRS)

The Vanderbilt Parent Rating Scale (VADPRS) was used to gain a more comprehensive understanding of each child and their unique ADHD presentation. The VADPRS is a measure of ADHD symptomology and includes questions pertaining to all 18 DSM-IV criteria for ADHD, in addition to criteria for assessing Oppositional Defiant Disorder and Conduct Disorder, which are both highly comorbid with ADHD (Bard et al., 2013). Parents rated the frequency of several behaviours on a 4-point Likert scale ranging from "never" to "very often". Clinical significance was determined based on scoring instructions outlined within the assessment materials. For example, the "inattentive subtype" was considered to be clinically significant if a parent rated their child as presenting behaviours "often" or "very often" 6 or more times on items 1 through 9 (See Table 1).

2.3.2 Behaviour Rating Inventory of Executive Functioning (BRIEF)

The Behaviour Rating Inventory of Executive Functioning (BRIEF), which is a measure of executive functioning, was also used to gain a better understanding of each participant. Typically, individuals with ADHD score in the clinical range given their deficits in executive functioning. The BRIEF is an 86-item questionnaire measuring eight aspects of executive functioning including inhibition, shifting, emotional control, initiation, working memory, planning and organization, order and organization, and monitoring (See Table 2).

2.4 Design

The study utilized a counterbalanced within-subjects design where each participant completed both the experimental and control conditions. The study consisted of three sessions that were each separated by one week; Day 1: Familiarization session, Day 2: Exercise condition, Day 3: Control condition. The experimental condition involved moderate intensity stationary biking and the control condition consisted of silent reading of an age-appropriate magazine. Experimental and control conditions were counterbalanced across participants so that some completed the exercise condition first while others completed the control condition first.

2.5 Procedure

2.5.1 Day 1: Familiarization and Questionnaire

Participants and their guardian(s) visited the lab for approximately 45 minutes to become familiarized with the study. Researchers explained the study protocol, what participants could expect during each session, and allowed children and their guardian(s) to ask questions. Guardians were given a Letter of Information and Consent form and had its contents orally described by a researcher. Children were given a Letter of Information and Assent form, which was also described orally. After obtaining consent from the guardian(s) and the child, one researcher sat down with the guardian(s) to gather demographic information and assisted them in completing two assessments to gain a better understanding of their child's ADHD status. At the same time, a second researcher took the child to an adjacent room and began familiarizing the participant with the executive functioning measures. This was done to increase comfort, help mitigate possible practice effects, and avoid poor performance on the first day of the study due to novelty. The child was also introduced to the stationary bike to ensure that they were comfortable and capable of safely completing the 10-minute bout of moderate intensity biking.

2.5.1.1 Guardian Protocol. Guardians were required to complete two assessments, the Vanderbilt Parent Rating Scale (VADPRS) and the Behaviour Rating Inventory of Executive Functioning (BRIEF). The results from the VADPRS and the BRIEF provided a more thorough description of participants' ADHD diagnosis. Lastly, guardians completed a demographic and medication questionnaire to provide information about their child including age, sex, and history of medication use (See Table 3).

2.5.1.2 Child Protocol. Meanwhile, another researcher had the child perform baseline measurements to gather information on their physical fitness. Participants removed their shoes and stepped onto a floor scale to measure their weight and stood against a vertical measuring tape to determine their height. They also performed a standing long jump task to measure explosive leg power (Ruiz et al., 2011). The measure required participants to jump from one stationary upright position as far forward as possible and land on both feet. Their distance was measured on a measuring tape from the back of their heels. Additionally, participants squeezed a handgrip dynamometer to obtain a measure of grip strength (Norman et al., 2011), which is an index of musculoskeletal health (Ruiz et al., 2011). For the purpose of the study, these physical fitness measures were combined to obtain an overall physical fitness score (See Table 4).

Participants also completed the Physical Activity Questionnaire for Older Children (PAQ-C; Appendix E). The PAQ-C is a 7-day recall instrument that assesses general physical activity levels throughout the week. The questionnaire consists of answering questions such as, "have you played basketball in the past 7 days? If yes, how many times per week?" The questionnaire was used to determine the child's self-reported physical activity behaviours. After the physical fitness tasks were performed and information about the participant's physical activity behaviours was collected, the researcher led the participant through the measures of executive functioning (Stroop Test, Trail Making Task, and the Leiter-3 Reverse Memory Span Task). This was done to familiarize participants with the tasks that they would be completing on the experimental and control days of the study. Lastly, participants got onto the stationary bike which was adjusted to their height. Once fitted to the stationary bike, participants biked for 10-minutes to ensure they were comfortable and capable of completing the experimental procedure.

2.5.2 Day 2: Exercise Condition

Participants were requested to refrain from taking medication 24 hours prior to experimental days in order to try and control for potential confounding variables. All medicated individuals reported that they did not take their medication 24 hours prior to the study. Participants returned to the lab the following week to complete the experimental condition, which involved 10-minutes of moderate intensity stationary biking. Though there are many forms and intensity levels of exercise utilized in various protocols, moderately-intense levels of exercise appear to consistently benefit executive functioning (Chang & Etnier, 2009; Pontifex et al., 2019). When participants arrived at the lab, they completed the battery of executive functioning measures (Stroop Test, Trail Making Task B, and Leiter-3 International Performance Scale Reverse Memory subtest) to acquire baseline executive functioning levels. These results were termed their “pre-intervention” scores. Following the executive functioning measures, they completed the biking protocol while wearing a Fitbit heart rate monitor on their wrist. The goal was to have participants keep their effort at a moderate level of intensity, which was determined by 65-85% of the maximum heart rate for their age using the equation 208 – (0.7 x age) (Kamijo et al., 2012; Machado & Denadai, 2011). Participants were told to stay within their target heart rate zone, which is between 130-170 beats per minute (bpm) for a 10-year old (Kamijo et al., 2012). Every 1 minute, researchers checked the Fitbit and recorded participants’ heart rate. Researchers provided appropriate instruction if participants were below or above the designated intensity level (i.e., they were instructed to peddle quicker if they were below or to peddle slower if they were above the designated level). Across all participants, the average heart rate was 117.5bpm. This falls slightly below 60% of the maximum heart rate for individuals between the ages of 10-14. Every 1 minute, researchers also asked participants to rate their perceived level of exertion (0= not working at all…5= strongly working…10= extremely strongly; see Appendix F). This information helped to ensure that the participant was not over working or under working relative to their own moderate intensity range. The average perceived exertion was 7.1, indicating that participants self-reported effort fell within the moderate intensity exercise range. Immediately following the 10-minute bout of biking, participants got off of the bike and the battery of executive functioning measures was re-administered. The tests immediately following the exercise component were termed “immediate post-intervention.” After these tests, participants silently read an age-appropriate children’s magazine for 10-minutes. Following the wait period, the researchers re-administered the executive functioning battery one more time to obtain “delayed post-intervention” scores. Participants’ outcomes at two time points were analyzed to assess the immediate impact of the exercise intervention, as well as the impact following a short delay.

2.5.3 Day 3: Control Condition

For the control condition, the same protocol as Day 2 was followed, however participants were asked to quietly read child-appropriate magazines for 10 minutes in lieu of the 10-minutes of biking. Once the final executive functioning battery was completed, guardians and participants were debriefed and were provided with compensation for their participation.

2.6 Calculation of Individual Difference Categories

Participants were independently assigned to a group for each individual difference factor. Using information on medication status that was provided in the demographic questionnaire, participants were either assigned to the “users” (n = 9) or “non-users” group (n = 6). One participant was excluded from the analysis as they did not indicate whether they took medication. In order to determine the high- and low-fit groups for the physical fitness factor, composite scores were created based on individuals’ physical fitness measures collected on familiarization day. Participants’ standing long jump scores were averaged between the two attempts and their overall grip strength was determined based on the combined average of both their right- and left-hand measures. Participants’ scores on these two measures were averaged to determine a “strength composite score.” Body Mass Index (BMI) percentile was also included as measure of physical fitness considering body composition is highly correlated with physical fitness level (Barlow, 2007; Centers for Disease Control and Prevention [CDC], 2020; Cote et al., 2013). BMI percentile was calculated using the CDC BMI Percentile Calculator for Children and Teens (CDC, 2020). This instrument is specifically designed to calculate BMI for individuals aged 2-19. The online tool calculates BMI using the standard formula, BMI = kg/m^2, while also considering age and sex (CDC, 2020). An individual's weight status was determined using age and sex-specific percentiles, which considers changes in body composition that vary with age and across sexes (CDC, 2020). Participants fell in the *Underweight* category if their BMI was below the 5^{th} percentile, based on their age and sex. The *Normal/Healthy Weight* category included participants whose BMI fell between the 5^{th} and 85^{th} percentile. Participants whose BMI was between the 85^{th} to 95^{th} percentile were placed in the *Overweight* category. Finally, the *Obese* category included participants who had a BMI that fell at the 95^{th} percentile or greater. Each of the categories were assigned either a score of 1 (underweight, overweight, or obese) or a 2 (normal weight) as a way to quantify the BMI categorization. The groups were given their respective scores as the categorizations of "underweight", "overweight" and "obese" were considered to include individuals who were less fit based on their body composition, whereas the "normal weight" categorization was thought to include individuals who were more physically fit. Using the quantified values for BMI, the strength composite scores for each participant was multiplied by the participants' BMI category and associated score value (1 or 2). For participants who fell in the "underweight", "overweight", or "obese categories", their strength composite score was multiplied by 1. For participants who fell within the "normal weight" range, their strength composite score was multiplied by 2. These values comprised the overall physical fitness level composite scores. A median split was conducted using the overall composite scores. Using Excel, the median value of all of the physical fitness level composite scores was calculated. Participants whose composite scores fell above the median were assigned to the "high-fit" group ($n = 8$) and participants whose overall composite score fell below the median was assigned to the "low-fit" group ($n = 8$).

Lastly, for physical activity behaviours, participants were assigned to either the "high-active" or the "low-active" group. Their categorization was based on their physical activity behaviours composite score which was derived following instructions outlined in the Physical Activity Questionnaire for Older Children (PAQ-C) Manual (Kowalski, Crocker, & Donen, 2004). A median split was conducted using the physical activity behaviour composite scores. Similar to the physical fitness factor, the median value of the physical activity behaviour composite scores was calculated using Excel. Participants whose composite scores fell above the median were assigned to the "high-active" ($n = 8$) group, and participants whose scores fell below the median was placed in the "low-active" group ($n = 8$).

2.7 Statistical Analyses

To answer all three research questions, several repeated measures ANOVAs were conducted, with a between-subjects factor of *group* (high vs. low), and a three-level within-subjects factor of *time* (pre-intervention, immediately post-intervention, and 10-minutes post-intervention). The measure of executive functioning (inhibitory control, working memory, task-switching) was used as the dependent variable. Analyses were conducted separately for the control and the exercise conditions. For inhibitory control, repeated measures ANOVAs were conducted for incongruent trials of the Stroop Test. The outcome variables were comprised of the number of words read minus the number of errors made. For task-switching, repeated measures ANOVAs were conducted for Trail Making Task B; outcome variables were comprised of time to complete the task in seconds. For working memory, repeated measures ANOVAs were conducted for the Leiter-3 Reverse Memory Span Task, where the outcome variable included the maximum number of items an individual held in their working memory. Independent Samples T-tests were also conducted to compare the means of the high and low groups at each time point to determine if there were statistically significant differences in executive functioning performance. Age and sex were included as covariates in the analyses if they were significant predictors of outcomes. The pre-intervention time point was also included as a covariate in the analysis if it was a significant predictor of outcome. When sphericity was violated, the Greenhouse-Geiser values were used.

Chapter 3: Results

3.1 Demographics and ADHD Screening Results

Table 1
Vanderbilt Parent Rating Scale (VADPRS) Results

	N	% of Sample
Inattentive Only		
Clinically significant	5	31.25
Not clinically significant	11	68.75
Hyperactive/Impulsive Only		
Clinically significant	1	6.25
Not clinically significant	15	93.75
Combined Subtype		
Clinically significant	7	43.75
Not clinically significant	9	56.25
Oppositional-defiant disorder		
Clinically significant	8	50.0
Not clinically significant	8	50.0
Conduct disorder		
Clinically significant	1	6.25
Not clinically significant	15	93.75
Anxiety		
Clinically significant	1	6.25
Not clinically significant	15	93.75
Performance		
Clinically significant	13	81.25

Not clinically significant	3	18.75

Table 2
Behavior Rating Inventory of Executive Function (BRIEF) Results

	N	% of Sample
Inhibition		
Clinically significant	7	43.75
Not clinically significant	9	56.25
Self-Monitor		
Clinically significant	10	62.5
Not clinically significant	6	37.5
Behaviour regulation index		
Clinically significant	10	62.5
Not clinically significant	6	37.5
Shift		
Clinically significant	13	81.25
Not clinically significant	3	18.75
Emotional Control		
Clinically significant	9	56.25
Not clinically significant	7	43.75
Emotion regulation index		
Clinically significant	10	62.5
Not clinically significant	6	37.5
Initiate		
Clinically significant	8	50

Not clinically significant	8	50
Working Memory		
Clinically significant	10	62.5
Not clinically significant	6	37.5
Planning		
Clinically significant	8	50.0
Not clinically significant	8	50.0
Task Monitoring		
Clinically significant	11	68.75
Not clinically significant	5	31.25
Organization		
Clinically significant	8	50.0
Not clinically significant	8	50.0
Cognitive regulation index		
Clinically significant	13	81.25
Not clinically significant	3	18.75

Table 3
ADHD Diagnoses and Medication Questionnaire Results

	Frequency (%)
Diagnosed with ADHD	
Yes	15 (93.8%)
No	1 (6.3%)
Age of Diagnosis	
4	1 (6.3%)

6	2 (12.5%)
7	4 (25%)
8	3 (18.8%)
9	4 (25%)
11	1 (6.3%)
Unanswered	1 (6.3%)
Age Noticed	
2	1 (6.3%)
3	3 (18.8%)
4	3 (18.8%)
5	2 (12.5%)
6	2 (12.5%)
7	1 (6.3%)
8	3 (18.8%)
Unanswered	1 (6.3%)
Prescribed medication	
Yes	13 (81.3%)
No	3 (18.8%)
Currently taking medication	
Yes	9 (56.3%)
No	6 (37.5%)
Unanswered	1 (6.3%)

Table 4
Participant Demographics

Characteristic	**Value**
Age of Child (years), mean *(SD)*	11.38 *(1.50)*
Sex of Participant	
Male	12
Female	4
Currently Taking Medication	
No response	1
Yes	9
No	6
Physical Fitness Scores	
Low	
Standing Long Jump (cm), mean *(SD)*	112.31 *(27.86)*
Grip Strength (both arms; lbs), mean *(SD)*	30.56 *(11.00)*
Body Mass Index (BMI), mean *(SD)*	22.39 *(7.28)*
Composite Score, mean *(SD)*	93.36 *(24.29)*
High	
Standing Long Jump (cm), mean *(SD)*	139.13 *(25.53)*
Grip Strength (both arms; lbs), mean *(SD)*	39.09 *(8.07)*
Body Mass Index (BMI), mean *(SD)*	18.18 *(1.34)*
Composite Score, mean *(SD)*	178.25 *(30.86)*
PAQ-C Scores (Physical Activity Behaviours)	
Low, mean *(SD)*	1.01 *(0.49)*

High, mean *(SD)*	2.71 *(0.43)*

Note: For the PAQ-C, a score of 1 indicates low physical activity behaviours whereas a score of 5 indicates high physical activity behaviours.

3.2 Research Question 1: How do individual differences in medication use influence the effect of an acute bout of exercise on executive functioning in children and youth with ADHD?

3.2.1 Control Condition

Regardless of medication status, participants performed similarly well on the Stroop Task (no main effect of time $F(2, 26) = 1.759$, $p = .192$, $\eta p^2 = .119$, no interaction $F(2, 26) = .521$, $p = .600$, $\eta p^2 = .039$, no between group effect $F(1, 13) = .879$, $p = .365$, $\eta p^2 = .063$), and they also performed similarly well on the Leiter-3 Reverse Memory Span Task (main effect of time $F(2, 24) = 4.719$, $p = .019$, $\eta p^2 = .282$, no interaction $F(2, 24) = .072$, $p = .930$, $\eta p^2 = .006$, no between group effect $F(1, 12) = .223$, $p = .645$, $\eta p^2 = .018$). However, with respect to performance on the Trail Making Task, participants who do not take medication for ADHD outperformed users of medication (no main effect of time $F(2,26) = .712$, $p = .500$, $\eta p^2 = .052$, no interaction $F(2, 26) = 2.248$, $p = .126$, $\eta p^2 = .147$, between group effect $F(1, 13) = 5.484$, $p = .036$, $\eta p^2 = .297$).

3.2.2 Exercise Condition

Similar to the Control condition, regardless of medication status, participants performed similarly well on the Stroop Task (no main effect of time $F(2, 26) = 1.462$, $p = .250$, $\eta p^2 = .101$, no interaction $F(2, 26) = .342$, $p = .713$, $\eta p^2 = .026$, no between group effect $F(1, 13) = .000$, $p = .991$, $\eta p^2 = .000$), and they also performed similarly well on the Leiter-3 Reverse Memory Span

Task (no main effect of time $F(2, 26) = 1.341$, $p = .279$, $\eta p^2 = .093$, no interaction $F(2, 26) = 1.341$, $p = .279$, $\eta p^2 = .093$, no between group effect $F(1, 13) = .219$, $p = .647$, $\eta p^2 = .017$). However, following the bout of exercise, medication use did not have any effect on task-switching performance. Participants' who were not taking medication performed similarly to those who take medication (no main effect of time $F(2, 26) = .279$, $p = .758$, $\eta p^2 = .021$, no interaction $F(2, 26) = 1.612$, $p = .219$, $\eta p^2 = .110$, no between group effect $F(1, 13) = .103$, $p = .753$, $\eta p^2 = .008$).

Overall, medication use did not predict inhibitory control or working memory performance in either the control or exercise condition. For task-switching performance, medication use predicted performance in the control condition such that those who were not taking ADHD medication outperformed those who are users of medication. However, following a 10-minute bout of biking, medication use was no longer a predictor of performance and all participants performed similarly well regardless of their medication status (see Table 5).

Table 5
Descriptive Statistics for Executive Functions based on Medication Use

	Medication Use	
	Non-User M *(SD)*	**User *M (SD)***
Inhibitory Control (Incongruent Stroop)		
Control Condition		
Pre-test	116.67 *(39.08)*	98.89 *(22.09)*
Immediate post-test	107.50 *(36.12)*	96.11 *(24.55)*
Delayed post-test	112.17 *(33.91)*	98.89 *(25.65)*
Acute Exercise Condition		
Pre-test	113.67 *(33.86)*	111.89 *(26.89)*
Immediate post-test	111.33 *(31.05)*	114.44 *(31.62)*
Delayed post-test	108.67 *(27.88)*	106.78 *(28.45)*

Working Memory (Leiter-3)		
Control Condition		
Pre-test	15.50 *(1.22)*	15.56 *(2.07)*
Immediate post-test	15.50 *(2.88)*	15.33 *(1.94)*
Delayed post-test	16.17 *(3.13)*	16.00 *(2.06)*
Acute Exercise Condition		
Pre-test	13.83 *(5.60)*	15.67 *(1.00)*
Immediate post-test	15.67 *(3.72)*	15.44 *(2.07)*
Delayed post-test	15.67 *(2.66)*	15.89 *(1.45)*
Task-Switching (TMT-B)		
Control Condition		
Pre-test	95.48 *(31.16)*	112.75 *(27.94)*
Immediate post-test	79.93 *(14.47)*	112.51 *(32.33)*
Delayed post-test	78.48 *(18.44)*	124.18 *(39.05)*
Acute Exercise Condition		
Pre-test	88.83 *(32.41)*	105.57 *(55.68)*
Immediate post-test	113.06 *(43.85)*	95.98 *(53.98)*
Delayed post-test	106.85 *(28.41)*	87.88 *(40.14)*

3.3 Research Question 2: How do individual differences in physical fitness levels influence the effect of an acute bout of exercise on executive functioning in children and youth with ADHD?

3.3.1 Control Condition

Regardless of participants' physical fitness level, they performed similarly well on the Stroop Task (no main effect of time F(1.377, 26) = .532, p = .594, ηp^2 = .039, no interaction F(2, 26) = .240, p = .789, ηp^2 = .018, no between group effect F(1, 13) = 1.387, p = .260, ηp^2 = .096), the Leiter-3 Working Memory Task (main effect of time F(2, 26) = 6.138, p = .007, ηp^2 = .321, no interaction F(2, 26) = .016, p = .984, ηp^2 = .001, no between group effect F(1, 13) = 1.751, p

= .209, ηp^2 = .119), and the Trail Making Task well (no main effect of time F(2, 28) = .475, *p* = .627, ηp^2 = .033, no interaction F(2, 28) = .129, *p* = .879, ηp^2 = .022, no between group effect F(1, 14) = .309, *p* = .587, ηp^2 = .022).

3.3.2 Exercise Condition

Similar to the control condition, regardless of participants' physical fitness level, they performed similarly well on the Stroop Task (no main effect of time F(2, 28) = 1.406, *p* = .262, ηp^2 = .091, no interaction F(2, 28) = 2.351, *p* = .114, ηp^2 = .144, no between group effect F(1, 14) = 2.719, *p* = .121, ηp^2 = .163), on the Leiter-3 Working Memory Task (no main effect of time F(2, 28) = 1.096, *p* = .348, ηp^2 = .073, no interaction F(2, 28) = 1.209, *p* = .314, ηp^2 = .079, no between group effect F(1, 14) = .747, *p* = .402, ηp^2 = .051), and on the Trail Making Task (no main effect of time F(2, 28) = .390, *p* = .681, ηp^2 = .027, no interaction F(2, 28) = .522, *p* = .599, ηp^2 = .107, no between group effect F(1, 14) = 1.684, *p* = .215, ηp^2 = .107).

While physical fitness level was not a statistically significant predictor of performance on any executive functioning task, the differences in group means suggest a potential emerging difference given an adequate sample size. Specifically, on every measure of executive functioning, individuals in the high-fit group appeared to be performing better (on average) than individuals in the low-fit group. This trend suggests greater improvements on executive functioning performance following an acute exercise bout, particularly for individuals in the high-fit group (see Table 6). While this suggests a potentially greater benefit of acute exercise for high-fit individuals, paired-samples t-tests revealed that participants with low physical fitness still showed improvements in their inhibitory control immediately following the acute exercise bout relative to when they were in the control condition (pre-test Stroop between low fitness Control vs. PA *t*(7) = -1.848, *p* = .107, *d* = 0.27; immediate post-test Stroop between low fitness

Control vs. PA *t*(7) = -2.870, *p* = .024, *d* = 0.28; delayed post-test Stroop between low fitness Control vs. PA *t*(7) = -.247, *p* = .812, *d* = 0.040). Thus, in low-fit individuals, inhibitory control did improve immediately after the exercise intervention, however those with lower fitness still did not reach a level equivalent to those with higher physical fitness.

Table 6

Descriptive Statistics for Executive Functions based on Physical Fitness Level

	Physical Fitness Level	
	Low **M *(SD)***	**High** ***M (SD)***
Inhibitory Control (Incongruent Stroop)		
Control Condition		
Pre-test	93.88 *(37.85)*	115.625 *(12.72)*
Immediate post-test	*88.75 (36.30)*	107.88 *(18.72)*
Delayed post-test	92.88 *(35.60)*	110.36 *(21.19)*
Acute Exercise Condition		
Pre-test	103.70 *(34.38)*	118.00 *(25.42)*
Immediate post-test	98.375 *(31.91)*	124.50 *(23.13)*
Delayed post-test	94.125 *(26.58)*	119.38 *(20.85)*
Working Memory (Leiter-3)		
Control Condition		
Pre-test	15.25 *(1.49)*	16.13 *(2.03)*
Immediate post-test	14.50 *(2.33)*	16.00 *(2.07)*
Delayed post-test	15.25 *(2.76)*	16.75 *(1.75)*
Acute Exercise Condition		
Pre-test	14.75 *(4.86)*	15.38 *(1.41)*
Immediate post-test	14.63 *(2.77)*	16.75 *(2.31)*
Delayed post-test	15.75 *(2.38)*	16.13 *(1.55)*
Task-Switching (TMT-B)		
Control Condition		
Pre-test	107.77 *(45.58)*	94.94 *(22.84)*
Immediate post-test	100.83 *(34.69)*	93.59 *(28.85)*

Delayed post-test	107.06 *(38.84)*	100.68 *(40.87)*
Acute Exercise Condition		
Pre-test	107.40 *(62.29)*	91.16 *(20.29)*
Immediate post-test	119.50 *(57.70)*	83.77 *(29.04)*
Delayed post-test	100.56 *(39.97)*	84.11 *(34.46)*

3.4 Research Question 3: How do individual differences in physical activity behaviours influence the effect of an acute bout of exercise on executive functioning in children and youth with ADHD?

3.4.1 Control Condition

Regardless of participants' physical activity behaviour, they performed similarly well on the Stroop Task (no main effect of time F(1.391, 28) = 2.091, *p* = .160, ηp^2 = .130, no interaction F(2, 28) = .230, *p* = .796, ηp^2 = .016, no between group effect F(1, 14) = 2.400, *p* = .144, ηp^2 = .146), the Leiter-3 Working Memory Task (no main effect of time F(1.298, 28) = 1.142, *p* = .317, ηp^2 = .075, no interaction F(2, 28) = 2.295, *p* = .119, ηp^2 = .141, no between group effect F(1, 14) = .957, *p* = .345, ηp^2 = .064), and the Trail Making Task (no main effect of time F(2, 28) = .476, *p* = .626, ηp^2 = .033, no interaction F(2, 28) = .173, *p* = .842, ηp^2 = .012, no between group effect F(1, 14) = .297, *p* = .594, ηp^2 = .021).

3.4.2 Exercise Condition

Similar to the control condition, regardless of participants' physical activity behaviour, they performed similarly well on the Stroop Task (no main effect of time F(1, 13) = .201, *p* = .661, ηp^2 = .015, no interaction F(1, 13) = 1.406, *p* = .257, ηp^2 = .098, no between group effect F(1, 13) = 1.406, *p* = .257, ηp^2 = .098), on the Leiter-3 Working Memory Task (no main effect of time F(2, 28) = 1.046, *p* = .365, ηp^2 = .070, no interaction F(2, 28) = .510, *p* = .606, ηp^2 = .035, no between group effect F(1, 14) = .336, p = .572, ηp^2 = .023), and on the Trail Making Task (no main effect of time F(2, 28) = .407, p = .670, ηp^2 = .028, no interaction F(2, 28) = 1.130, p = .337, ηp^2 = .075, no between group effect F(1, 14) = .551, p = .470, ηp^2 = .038). Overall, physical activity behaviour was not predictive of performance on any executive functioning task regardless of condition exposure (see Table 7).

Paired samples t-tests were conducted to determine if there were any differences in how participants performed in the control condition compared to the exercise condition. While there appears to be some emerging evidence demonstrating improvements in performance between the control and exercise conditions, analyses revealed no statistically significant differences between performance on any executive functioning measure when comparing participants group-performance between the control and exercise conditions. This demonstrates that participants' executive functioning performance did not significantly improve following the exercise condition regardless of high-active or low-active groupings.

Table 7
Descriptive Statistics for Executive Functions based on Physical Activity Behaviour

	Physical Activity Behaviours	
	Low **M *(SD)***	**High** ***M (SD)***
Inhibitory Control (Incongruent Stroop)		
Control Condition		
Pre-test	94.63 *(20.43)*	114.88 *(34.83)*
Immediate post-test	88.38 *(26.45)*	108.25 *(30.85)*
Delayed post-test	89.75 *(25.38)*	113.50 *(30.42)*
Acute Exercise Condition		
Pre-test	93.38 *(18.25)*	128.38 *(30.18)*
Immediate post-test	96.13 *(30.11)*	126.75 *(29.78)*
Delayed post-test	97.00 *(22.59)*	116.50 *(27.89)*

Working Memory (Leiter-3)		
Control Condition		
Pre-test	15.63 *(2.13)*	15.75 *(1.49)*
Immediate post-test	15.63 *(2.32)*	14.88 *(2.30)*
Delayed post-test	17.00 *(2.33)*	15.00 *(2.07)*
Acute Exercise Condition		
Pre-test	15.75 *(1.67)*	14.38 *(4.69)*
Immediate post-test	15.75 *(2.05)*	15.63 *(3.38)*
Delayed post-test	16.25 *(1.75)*	15.63 *(2.20)*
Task-Switching (TMT-B)		
Control Condition		
Pre-test	107.26 *(39.57)*	95.45 *(27.98)*
Immediate post-test	99.25 *(33.74)*	95.17 *(30.29)*
Delayed post-test	108.88 *(43.88)*	98.86 *(34.91)*
Acute Exercise Condition		
Pre-test	106.80 *(58.58)*	91.76 *(29.69)*
Immediate post-test	116.07 *(51.83)*	87.20 *(41.71)*
Delayed post-test	90.70 *(42.02)*	93.97 *(34.17)*

Chapter 4: Discussion

The purpose of this study was to examine how three individual difference factors (medication use, physical fitness level, physical activity behaviours) impacted the effectiveness of an acute bout of exercise for improving executive functioning in children and youth with ADHD. We found that medication use did not predict inhibitory control or working memory performance in either the control or the acute exercise condition. However, in the control condition, medicated individuals outperformed non-medicated individuals on a measure of task-switching. This effect was no longer seen following 10 minutes of moderate-intensity biking, suggesting that the acute exercise bout equalized initial differences in task-switching performance. Further, physical fitness level did not predict performance on any of the measures of executive functioning. However, there does appear to be emerging evidence to suggest that high-fit individuals are at an advantage as they demonstrated greater average performance on all measures of executive functioning. We believe these results were not supported by significant results due to a combination of insufficient sample size, high performance variance, or potentially a weak exercise stimulus. These limitations will be discussed in the following paragraphs. Lastly, regardless of condition exposure, physical activity behaviour was not predictive of performance on any executive functioning task. However, similar to physical fitness, some emerging trends in the data suggested that on average those who engage in more physical activity behaviours have better inhibitory control than those who engage in fewer physical activity behaviours.

4.1 Individual Differences in Medication Use and its Impact on an Acute Exercise Intervention

Supporting our initial hypothesis, we did not find differences in how users and non-users of medication responded to the exercise intervention on measures of inhibitory control or working memory. However, in the control condition we did find that non-medicated participants outperformed medicated participants on a measure of task-switching. Interestingly, following a 10-minute bout of exercise, participants' medication-use was no longer a predictor of task-switching performance. This suggests that a 10-minute bout of exercise may level the effects of medication use on task-switching. Overall, these findings are consistent with previous work revealing that deficits in executive functioning associated with ADHD can be enhanced by exercise regardless of participants' medication use (Chang et al., 2012b; Christiansen et al., 2019; Medina et al., 2010).

It is unclear exactly why non-medicated participants performed significantly better than medicated participants in the control condition. It could be that the removal of medication, a requirement to participate in the study, had a negative impact on performance for those used to taking medication. For example, Fox and colleagues (2014) conducted a study to determine the impact that the removal of methylphenidate (a common stimulant medication taken by children with ADHD) had on executive functioning performance. The researchers revealed that the discontinuation of methylphenidate significantly reduced individuals' performance on a learning and motor skill task (Fox, Adi-Japhab, & Karni, 2014). They concluded that adolescents with ADHD who are treated daily with medication, but skip a dose, show significantly reduced performance relative to their performance when they have taken medication (Fox, Adi-Japhab, & Karni, 2014). Thus, in the current study, the removal of medication may have led to decreased performance in the control condition. This negative effect may have been ameliorated by the exercise intervention. As previously mentioned, exercise has proven to be efficacious in mitigating executive functioning deficits, including task-switching performance. The reasons for this are many fold, but are based on the premise that exercise can support the neurological structures and executive functions associated with dysfunction in ADHD. In the current study, deficits in task-switching performance may have been enhanced through exercise due to its impact on the neurological structures responsible for controlling executive functioning performance.

4.2 Individual Differences in Physical Fitness and its Impact on an Acute Exercise Intervention

The current study revealed no statistically significant differences in performance between high-fit and low-fit individuals on any measure of executive functioning. These findings align with those from Ludyga and colleagues (2016) who demonstrated that all participants performed similarly well on various measures of executive functioning regardless of physical fitness level. They revealed that physical fitness level does not moderate the relationship between exercise and executive functioning. While the results of the current study appear to be most consistent with findings from Ludyga and colleagues (2016), the pattern of our data suggests potential differences in performance as a function of fitness level (see Table 6). Specifically, there were marked differences among group means between low-fit and high-fit groups shown on measures of inhibitory control, working memory, and task-switching. Importantly, Chang and colleagues (2015) reported a similar finding; individuals who were more physically fit experienced greater benefits on inhibitory control performance following a short bout of exercise compared to those who were less physically fit. Although not supported statistically, the current pattern of data does suggest that high-fit individuals may perform better than low-fit individuals on an inhibitory control measure. In addition, we also found that *both* high-fit and low-fit individuals' executive functioning performance improved following a 10-minute bout of exercise. While both groups experienced some benefit from the exercise intervention, individuals in the high-fit group appeared to be experiencing a greater benefit. This trend appears to be consistent across all of the measures of executive functioning.

There are several potential explanations for these findings. First, the increased benefits of acute exercise for individuals with higher physical fitness levels may be facilitated by existing brain resources (Chang et al., 2015). Specifically, high-fit individuals have demonstrated greater default mode network connectivity, which provides a stronger pathway for improved executive functioning (Voss et al., 2010). Additionally, individuals with higher physical fitness levels exhibit greater gray matter volume in a host of brain regions including the PFC, which is essential for executive functioning (Weinstein et al., 2012). Greater gray matter volume within the PFC is thought to mediate the relationship between physical fitness levels and executive functioning, specifically inhibitory control (Weinstein et al., 2012). Greater gray matter volume is typically indicative of better executive functioning performance, however the exact mechanisms supporting this relationship are less understood (Raz et al., 2004; Weinstein et al., 2012).

These patterns in the data can be understood within the Aptitude-Treatment Interaction framework which suggests that there may be certain characteristics that can influence an individual's responsivity to an intervention (Snow, 1991). Within the current study, participants with higher physical fitness appear to demonstrate enhanced executive functioning performance following the exercise intervention which may be facilitated by pre-existing brain resources. This suggests that greater levels of physical fitness may promote an individuals' responsiveness to an exercise intervention.

While the current study points to potential emerging differences between high-fit and low-fit individuals, there are some possible explanations as to why the results did not reach statistical significance. Firstly, we did not reach our intended sample size of 30 participants. Given that the current study only had about half of the intended participants, the lack of statistically significant findings could be due to low power. Additionally, low power may have contributed to a high degree of performance variance between participants. Another possibility for the lack of significant findings could be that participants did not meet the threshold for moderate-intensity exercise. As mentioned earlier, the average heart rate across all participants fell slightly below 60% of the maximum heart rate for individuals between the ages of 10-14. Conversely, the average rating of perceived exertion indicated a self-reported moderate intensity exercise range. This suggests that participants perceived their effort to be in the moderate-intensity range when in fact their actual effort was below the threshold for moderate-intensity exercise. The influence of exercise intensity on the magnitude of executive functioning benefits is well-documented (Lambourne & Tomporwski, 2010; Ludyga et al., 2016). Exercise intensity is thought to influence executive functioning performance in an "inverted-U effect", such that moderate-intensity exercise elicits the greatest improvements in executive functioning, compared to light or heavy intensity exercise (Córdova et al., 2009; Ludyga et al., 2016; Lowe et al., 2014; McMorris & Hale, 2012). Given that individuals typically experience greater improvements in their executive functioning following moderate-intensity exercise, participants in the current study may not have experienced executive functioning benefits to the same degree as they did not meet the threshold for moderate-intensity exercise.

On a similar note, the lack of significant findings may be due to an insufficient exercise modality. Specifically, in order to elicit improvements in executive functioning, the exercise intervention may have needed to be longer in duration or have included a cognitively engaging component. Previous research involving acute exercise interventions have typically incorporated exercise durations that are at least 15 minutes long. Specifically, Benzing and colleagues (2018) demonstrated that 15 minutes of acute exercise improved task-switching performance in 8–12-year-olds with ADHD, while Piepmeier and colleagues (2015) found that 30 minutes of biking led to significant improvements in inhibitory control among children with ADHD. In addition to duration of the exercise intervention, the inclusion of a cognitively engaging component may also increase the likelihood of improving executive functioning performance. Exercise interventions that are cognitively engaging include the addition of a task that requires goal-directed behaviour (Crova et al., 2014). This could include individual or team sports, which require the integration of exercise and cognitive processing to anticipate others behaviour, employ strategies, and adapt to changes in task demands. For example, Benzing (2018) utilized an exergaming program, where participants engaged in a video game while completing various physically and mentally demanding tasks. Additionally, Pesce and colleagues (2009) used team games as part of their cognitively demanding exercise intervention. It is likely that cognitively demanding exercise interventions increase cognitive engagement and thus the allocation of cognitive resources (Schmidt et al., 2015). As a result, individuals may experience enhanced executive functioning performance on subsequent tasks as a result of pre-activation of the same brain regions. Supporting this idea, Schmidt and colleagues (2015) compared participants executive functioning following either a simple bout of exercise or a cognitively complex bout of exercise. Individuals who completed the cognitively demanding exercise demonstrated improved task-switching performance, whereas the participants who completed the simple exercise bout did not show improvements to the same degree. Other studies have used various forms of cognitively engaging exercise such as completing math problems while engaging in the exercise (Vazou & Smiley-Oyen, 2014), exergaming (Benzing et al., 2018), and the inclusion of group and team games (Jäger et al., 2015; Pesce et al., 2009). These studies revealed improvements in executive functioning (inhibitory control, cognitive flexibility, and task-switching, respectively), following a cognitively demanding bout of exercise. Importantly, the demands of cognitively engaging exercise are similar to those of executive functioning (Best, 2010). This suggests that the cognitive engagement that participants experience during cognitively demanding exercise interventions may persist and therefore enhance executive functioning on tasks that follow (Best, 2010). Opposingly, repetitive exercises such as stationary biking or running on a treadmill are not cognitively demanding as they do not require the same degree of thought or cognitive skills. While exercise interventions alone influence executive functioning performance, the interaction of exercise and cognitively engaging tasks produces an even stronger effect (Best, 2010; Ziereis, 2015). The lack of a cognitively demanding bout of exercise in the current study may, in part, explain why we did not find significant improvements in executive functioning.

4.3 Individual Differences in Physical Activity Behaviour and its Impact on an Acute Exercise Intervention

The current study revealed that physical activity behaviour was not predictive of performance on any measure of executive functioning. However, similar to physical fitness, physical activity behaviours did yield some emerging evidence for group differences between high-active and low-active individuals (see Table 7). Specifically, on the inhibitory control task, paired-samples t-tests revealed some improvements in performance from the control condition to the exercise condition, particularly for high-active individuals. While both the low-active and high-active groups seem to be demonstrating improved performance following the exercise intervention relative to the control condition, the high-active individuals appear to be experiencing a greater benefit to their inhibitory control. A similar pattern was seen for task-switching performance, where the high-active individuals appear to be showing greater improvements following the exercise condition. However, these are simply patterns in the data that we can speak to and will require validation with appropriate statistics when there is an adequate sample size in the future.

4.4 Limitations

This study has highlighted important aspects of the impact of individual difference factors among children with ADHD, but it is not without limitations. Firstly, we fell well below our ideal sample size of 30. This limited our power and may have contributed to the lack of significant findings. The lack of an age-matched control group hinders our ability to determine if the impact of individual difference factors in the current study are unique to children with ADHD or if a similar result would be seen in a sample of typically developing children. Future research will add an age-matched control group to further refine our understanding of individual difference factors and their role in acute exercise interventions. Additionally, the study included participants who take medication to reduce ADHD symptomology. Although participants were asked to refrain from taking their medication 24-hours prior to experimental days, it is possible that there were lasting implications from medication that could have impacted participants performance on the executive functioning tasks. Another potential limitation that may have impacted the results of the study includes the measures used to calculate physical fitness level. While grip-strength and standing long jump are validated measures of musculoskeletal health (Ruiz et al., 2011), BMI may not be the most accurate predictor of physical fitness level. It is possible that the BMI percentile categorizations and their associated values (ie. 1 or 2) did not measure physical fitness level, but rather provided a measure of body composition. As a result, participants may not have received the most appropriate categorization. Future research may want to consider different measures of physical fitness level.

4.5 Implications for Future Research and Conclusion

To our knowledge, this was the first study to examine individual difference factors and their role in influencing an acute exercise bout in children and youth with ADHD. Importantly, we demonstrated that a 10-minute bout of exercise helped equalize initial differences in task-switching performance between medicated and non-medicated individuals. The current study also points to potential emerging evidence for group differences between high-fit and low-fit individuals. This suggests that following a bout of exercise, high-fit individuals may be experiencing a greater benefit to their executive functioning compared to low-fit individuals. While the high-fit individuals may be at a greater advantage, our results demonstrated that low-fit individuals are still benefiting from the intervention and experience improvements to their executive functioning following an acute bout of exercise. Future research should examine a larger sample size, the addition of an age-matched control group, and potentially a longer and/or more cognitively engaging bout of exercise. Nonetheless, this work provides important insight on three individual difference factors and their influence on the relationship between acute exercise and executive functioning among children and youth with ADHD and will help pave the way for future research.

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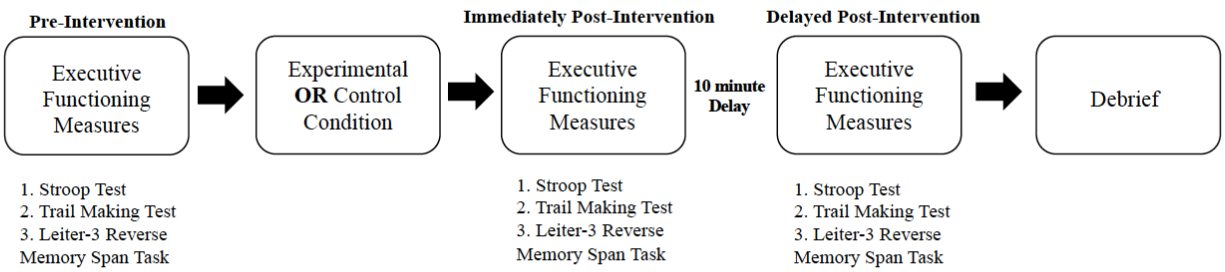
Appendices

Appendix A

Flow of the Study



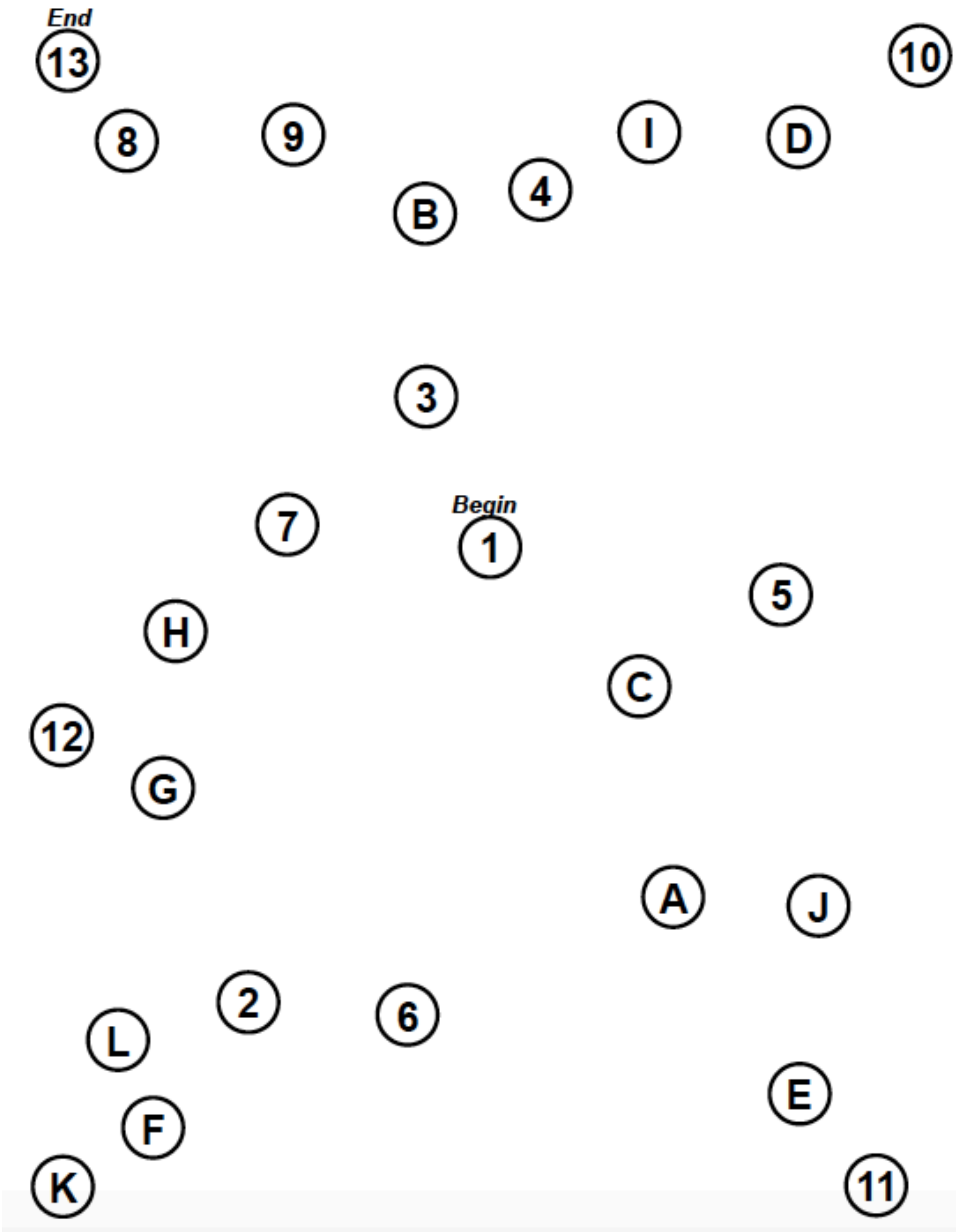
Appendix B

Incongruent Stroop Task

BLACK	BLACK
GREEN	ORANGE
BLUE	RED
RED	GRAY
YELLOW	GRAY
ORANGE	GREEN
RED	ORANGE
BLUE	BLACK
ORANGE	BLUE
GREEN	RED
GRAY	BLUE
BLACK	YELLOW
YELLOW	RED

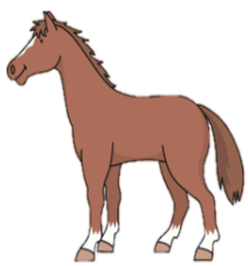
Appendix C

Trail Making Task B



Appendix D

Working Memory Task

Appendix E

Physical Activity Questionnaire (PAQ-C): Physical Activity in the Last 7 Days

Activity and Number of Times per Week	**Frequency (%)**
Skipping	
0	9 (56.3%)
1	4 (25%)
2	1 (6.3%)
3	1 (6.3%)
4	1 (6.3%)
Rowing	
0	15 (93.8%)
1	1 (6.3%)
Inline Skating	
0	15 (93.8%)
1	1 (6.3%)
Tag	
0	5 (31.3%)
1	7 (43.8%)
2	1 (6.3%)
3	2 (12.5%)
4	1 (6.3%)
Walking	
0	3 (18.8%)
1	5 (31.3%)
2	2 (12.5%)
3	3 (18.8%)
4	3 (18.8%)
Biking	
0	7 (43.8%)
1	2 (12.5%)
2	3 (18.8%)
3	4 (25%)
4	
Jogging	
0	6 (37.5%)
1	2 (12.5%)
2	3 (18.8%)
3	3 (18.8%)

4	1 (6.3%)
5	1 (6.3%)
Aerobics	
0	15 (93.8%)
1	1 (6.3%)
Swimming	
0	10 (62.5%)
1	2 (12.5%)
2	3 (18.8%)
3	1 (6.3%)
Baseball	
0	15 (93.8%)
1	1 (6.3%)
Dance	
0	11 (68.8%)
1	2 (12.5%)
2	2 (12.5%)
3	1 (6.3%)
Football	
0	14 (87.5%)
1	1 (6.3%)
2	1 (6.3%)
Badminton	
0	15 (93.8%)
1	1 (6.3%)
Skateboarding	
0	16 (100%)
Soccer	
0	13 (81.3%)
1	2 (12.5%)
2	1 (6.3%)
Street Hockey	
0	16 (100%)
Volleyball	
0	14 (87.5%)
1	2 (12.5%)

Floor Hockey	
0	14 (87.5%)
1	1 (6.3%)
2	1 (6.3%)
Basketball	
0	11 (68.8%)
1	3 (18.8%)
2	1 (6.3%)
3	1 (6.3%)
Ice Skating	
0	15 (93.8%)
1	1 (6.3%)
Cross-Country Skiing	
0	16 (100%)

Activity Within Last 7 Days During PE Class	
I don't do PE	2 (12.5%)
Hardly ever	4 (25%)
Sometimes	4 (25%)
Quite often	3 (18.8%)
Always	3 (18.8%)
Activity During Recess	
Sat down	3 (18.8%)
Stood around	5 (31.3%)
Ran or played a bit	2 (12.5%)
Ran and played quite a bit	2 (12.5%)
Ran and played hard	4 (25%)
Activity During Lunch	
Sat down	10 (62.5%)
Stood around	2 (12.5%)
Ran or played a bit	1 (6.3%)
Ran and played quite a bit	3 (18.8%)
Ran and played hard	
How many days right after school were you active?	
0	6 (37.5%)
1	1 (6.3%)
2-3	4 (25%)
4	2 (12.5%)
5	3 (18.8%)

How many days in the evening were you active?	
0	6 (37.5%)
1	2 (12.5%)
2-3	4 (25%)
4	1 (6.3%)
5	3 (18.8%)
On the weekend how many times were you active	
0	5 (31.3%)
1	2 (12.5%)
2-3	2 (12.5%)
4-5	3 (18.8%)
6 or more	4 (25%)
How often did you do activity on Monday?	
0	2 (12.5%)
1	4 (25%)
2	6 (37.5%)
3	2 (12.5%)
4	2 (12.5%)
How often did you do activity on Tuesday?	
0	3 (18.8%)
1	4 (25%)
2	3 (18.8%)
3	5 (31.3%)
4	1 (6.3%)
How often did you do activity on Wednesday?	
0	2 (12.5%)
1	3 (18.8%)
2	3 (18.8%)
3	3 (18.8%)
4	5 (31.3%)
How often did you do activity on Thursday?	
0	3 (18.8%)
1	3 (18.8%)
2	7 (43.8%)
3	2 (12.5%)
4	1 (6.3%)
How often did you do activity on Friday?	
0	2 (12.5%)
1	6 (37.5%)
2	2 (12.5%)

3	2 (12.5%)
4	4 (25%)
How often did you do activity on Saturday?	
0	6 (37.5%)
1	3 (18.8%)
2	2 (12.5%)
3	3 (18.8%)
4	2 (12.5%)
How often did you do activity on Sunday?	
0	7 (43.8%)
1	2 (12.5%)
2	2 (12.5%)
3	1 (6.3%)
4	4 (25%)

Appendix F

Ratings of Perceived Physical Exertion (RPE) Scale

Ratings of Perceived *PHYSICAL* Exertion (RPE)

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Human kinetics.

0 Nothing at all

0.3

0.5 Extremely weak

1 Very weak

1.5

2 Weak

2.5

3 Moderate

4

5 Strong

6

7 Very Strong

8

9

10 Extremely Strong

11

12 Absolute Maximum

Appendix G

Ethics Approval Letter

Date: 15 March 2019

To: Dr Barbara Fenesi

Project ID: 113304

Study Title: Understanding the effects of acute exercise and mindfulness on cognitive functioning in children with ADHD using advanced functional imaging techniques

Application Type: HSREB Initial Application

Review Type: Full Board

Meeting Date: 15/Jan/2019

Date Approval Issued: 15/Mar/2019

REB Approval Expiry Date: 15/Mar/2020

Dear Dr Barbara Fenesi

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date
Appendix 10 - Affect	Other Data Collection Instruments	Received March 14, 2019
Appendix 11 - Motivation Questionnaire	Other Data Collection Instruments	Received March 14, 2019
Appendix 12 - Self-efficacy	Other Data Collection Instruments	Received March 14, 2019
Appendix 13 - Mood Questionnaire	Other Data Collection Instruments	Received March 14, 2019
Appendix 2 - Vanderbilt Assessment	Paper Survey	Received March 14, 2019
Appendix 3 - C-PAQ	Paper Survey	Received March 14, 2019
Appendix 4 - Demographics and Medication (1)	Paper Survey	Received March 14, 2019
Appendix 5 - Stroop Task	Other Data Collection Instruments	Received March 14, 2019
Appendix 6 - Trail Making Task	Other Data Collection Instruments	Received March 14, 2019
Appendix 9 - Rating of Perceived Exertion	Other Data Collection Instruments	Received March 14, 2019
Assent ADHD mar 13	Assent Form	Received March 14, 2019
Assent Control mar 13	Assent Form	Received March 14, 2019
EmailAttachment_12.9 (3)	Email Script	Received March 14, 2019
LOI-C (Control) Mar 13	Written Consent/Assent	Received March 14, 2019
LOI-C(ADHD)	Written Consent/Assent	Received March 14, 2019
RecruitmentFlyer_ADHDGroup_12.5 (2)	Recruitment Materials	09/Feb/2019
RecruitmentFlyer_Age-matchedcontrol_12.5(2)	Recruitment Materials	09/Feb/2019
Study Protocol	Protocol	08/Feb/2019
Telephone_Script_12.9(1)	Telephone Script	Received March 14, 2019

No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB , except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopaul, Ethics Officer on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Jasmyn Skinner
Curriculum Vitae

Post-secondary Education and Degrees:

MA Counselling Psychology
Western University
London, Ontario, Canada
2019-2021

BAS (Honours), Neuroscience and Psychology
University of Guelph
Guelph, Ontario, Canada
2015-2019

Honours and Awards:

Social Sciences and Humanities Research Council (SSHRC) Scholarship
2020-2021

Brenda Whiteside Award
2019

Kevin Durie Memorial Scholarship
2018

Related Work And Volunteer Experience:

Graduate Psychological Intern
Thames Valley District School Board, London, ON
2020-2021

Crisis Responder
Kids Help Phone
2020-2021

Robert Macmillian Symposium in Education, Executive Committee Member
Western University
2020-2021

Graduate Student Assistant – Conference Coordinator for Volunteers
Western University
2020

Student Support Network Volunteer
University of Guelph
2018-2019

Publications:

Fenesi, B., Graham, J., Crichton, M., Ogrodnik, M., & **Skinner, J**. (Under Review). Physical Activity in High School Classrooms - A Promising Avenue for Future Research. *Journal of Adolescence.*

Fiacconi, C., Mitton, E., Laursen, S., & **Skinner, J.** (2019). Isolating the Contribution of Perceptual Fluency to Judgements of Learning. *Journal of Experimental Psychology: Learning, Memory and Cognition*