The Effect of Acute Exercise on Attentional Processes in Typically Developing Children and Youth

by

Dana Higginbotham

Submitted in partial fulfilment of the requirements
for the degree of Master of Arts in School Psychology

at

Mount Saint Vincent University
Halifax, Nova Scotia
September 29th, 2014

Table of Contents

Abstract

Previous research has found that a variety of exercise interventions result in improved neurocognitive functioning and attention in typically developing and clinical populations. This was a preliminary study to examine whether an acute exercise intervention (i.e., 30 minutes of vigorously intense cardiovascular exercise) improves attention, as measured by the Test of Everyday Attention in Children (TEA-Ch). It was hypothesized that there would be differential improvements across various attentional processes (i.e., selective attention, divided attention, sustained attention, attentional control/switching). Results indicate that the exercise intervention lead to significant for attentional control/switching. This study adds to previous research by giving a more thorough examination of how an exercise intervention impacts various attentional processes. Findings support recommendations to use exercise interventions, alone or in combinations with other supports, to reduce inattention at home and in the classroom.

CHAPTER ONE

Literature Review

Executive Functioning

Executive functioningencompasses a cluster of higher-order cognitive processes that allow an individual to effectively and efficiently perform future-orientated or goal-directed tasks(Banich, 2009; Berlin, Bohlin, & Rydell, 2003). As such, executive functioning is the capacity to control thoughts and behaviours, which requires abilities such as filtering out irrelevant information, developing and following through with a plan, and inhibiting impulses (Blakemore & Choudhury, 2006). Executive functions have been extensively researched over the past 10 years, with the focus of this research being the development of executive functioning in both typically developing individuals and certain clinical populations believed to have impaired executive functioning (e.g., Attention-Deficit Hyperactivity Disorder, Antisocial Personality Disorder, Schizophrenia, Obsessive-Compulsive Disorder, and Traumatic Brain Injury; Alvarez & Emory, 2006; Sergeant, Geurts, & Oosterlaan, 2002; Morgan & Lilienfeld, 2000; Nieuwenstein, Aleman, & de Haan, 2001; Perry, Potterat, & Braff, 2001).

Historical Background of Executive Functioning

Early research in the area of executive functioning was the result of scientists becoming aware of specific groups of individuals who appeared to have an *absence* of executive abilities. For example, brain injury patients were among the first to be studied for executive functioning impairments because as a group, these individuals reportedly had difficulty controlling and regulating their behaviour (Miyake et al., 2000; Suchy, 2009). The case study of Phineas Gage, a railroad foreman from the 1840s, is one of the earliest and best-known cases of an individual with impaired executive functioning. He was involved in a work accident that resulted in a tamping iron penetrating his skull, which caused damage to his frontal lobe. Although he survived the incident, he experienced a drastic change in temperament; he went from being well liked and even-tempered to someone who was socially and behaviourally inappropriate and emotionally dysregulated (Suchy, 2009). The connection between the frontal lobe and executive functioning was not formally documented until more than a century later, however. Alexander Luria, a neuropsychologist, was the first to formally document deficits in executive functioning, which he first described in the 1960s. Luria described the relationship between frontal lobe injuries and the resulting difficulties with social, emotional, and behavioural functioning, a disorder that he coined as “frontal-lobe syndrome” (Luria, 1979; Luria, Homskaya, & Bllinkov, 1967).

Since this early description, the terminology and understanding of the role of the frontal lobes has changed considerably. It is now understood that impairments in executive functioning do not occur exclusively in brain-damaged patients; rather, these impairments can also be naturally occurring (Cicchetti, 2002; Goldsmith & Rogoff, 1997; Lenguna et al., 2007; Li-Grining, 2007; Lipina, Martelli, Vuelta, & Colombo, 2005). There is also a better understanding of how different regions of the brain are implicated in executive functioning. In contrast to the previous view that executive functioning occurred exclusively in the prefrontal cortex, the front-most region of the frontal cortex, it is now believed that damage to regions outside of the prefrontal cortex can also result in similar impairments. This is largely the result of the connectedness of the prefrontal cortex to other cortical regions (Suchy, 2009). Given that the patterns of impairments observed are no longer considered to result from damage to the prefrontal cortex exclusively, the terminology has shifted from “frontal-lobe syndrome” to “executive functions”, where an impairment in one or more of these skills is conceptualized as an “executive dysfunction” (Gioia, Isquith, & Guy, 2001; Lezak, 1982).

Another important development is that executive functioning is no longer conceptualized as being a single, unitary construct. Previously, it was believed that an individual either had impaired or unimpaired executive functioning. However, given that global impairment of executive functioning is quite rare, the conceptualization has shifted to an understanding that it is multiple, related systems that function in unison to control and manage an individual’s behavior (Alexander & Stuss, 2000). Therefore, it is possible to have impairment in one or more of the executive functioning processes.

Executive Function Processes

Although it is currently recognized that executive functioning encompasses multiple, inter-related processes, it is still debated which processes should be subsumed under the executive function umbrella. Based on factor analyses and neuropsychological theory, a widely accepted model divides executive functioning into four distinct domains, which include (1) attentional control; (2) information processing; (3) cognitive flexibility; and (4) goal setting (Anderson, 2002; Alexander & Stuss, 2000).

Attentional control. Attentional control is important for tasks that require an individual to selectively attend to a specific stimuli, sustain attention over an extended period of time, and monitor activities so tasks are completed in the proper order, errors are identified, and goals are achieved. Therefore, specific processes encompassed by the attentional control domain include selective attention (i.e., the ability to process relevant stimuli while filtering out unrelated stimuli), self-regulation, self-monitoring, and inhibition (i.e., deliberately curtailing an automatic behaviour or response; Leung, Skudlarski, Gatenby, Peterson, & Gore, 2000; Miyake & Friedman, 2012). As a result, individuals with impairment in one or more of these processes typically demonstrate impulsivity, failure to complete tasks, and careless mistakes (Anderson, 2002; Barkley, 1997; Christ, Kanne, &Reierson, 2010; Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000).

Information processing. Information processing is the ability to detect changes in information that is processed. As such, it is typically thought to require the use of various cognitive domains, including memory, processing speed, attention, and representational competence (Rose, Feldman, & Jankowski, 2009). Therefore, information processing is important for tasks that require fluency, efficiency, and quick speed of processing. As such, a deficit in one or more of these processes typically results in a reduction in output (e.g., verbal, written) and difficulties on tasks that are timed or require quick retrieval of information (Anderson, 2002; Barkley, 1997; Christ et al., 2010; Miyake et al., 2000).

Cognitive flexibility. Cognitive flexibility encompasses working memory, divided attention (i.e., the ability to process multiple stimuli at one time), shifting (i.e., the ability to switch flexibly across tasks or mental sets), and learning and re-strategizing based on previous experiences (Anderson, 2002; Barkley, 1997; Christ et al., 2010; Miyake et al., 2000). Therefore, individuals who have difficulty with cognitive flexibility are often considered to be rigid and ritualistic. Typically these individuals have difficulty adjusting to change and engage in perseverative behaviours (Anderson, 2002; Barkley, 1997; Christ et al., 2010; Miyake et al., 2000).

Goal setting. Goal setting is important for planning an activity in advance, having an efficient and strategic approach to a given task, and developing new initiatives or concepts. As such, the specific abilities that fall under the goal setting domain include initiative, conceptual reasoning, planning, and strategic organization. Difficulty with problem solving tasks is common among individuals with impairment in one or more of the processes that fall within this domain (Anderson, 2002; Barkley, 1997; Christ et al., 2010; Miyake et al., 2000).

Neural Underpinnings of Executive Functioning

Historically the prefrontal cortex, the anterior region of the brain, was considered the exclusive neuroanatomical structure responsible for executive functioning (Suchy, 2009). Current understanding, however, recognizes that the prefrontal cortex is only one part of an executive system (Duffy & Campbell, 2001). Given the inter-connectedness of the prefrontal cortex to virtually all other regions of the brain (Suchy, 2009), executive functioning processes require integration between the prefrontal cortex and many other regions, including the basal ganglia, thalamus, cerebellum, and all cortical regions outside of the prefrontal cortex (Aron, 2008). For example, Leung et al. (2000) conducted a functional magnetic resonance imaging (MRI) study to examine the specific regions that are activated during the Stroop word-colour task (see page 17 for a description of this task), a commonly used measure of selective attention and inhibition. Results showed consistent activation during this task in the anterior cingulate, insula, inferior frontal, middle frontal, parietal, and mid-temporal regions.

Although clearly dependent on several other neural systems, the prefrontal cortex is important to also consider in isolation, given that it is the structure that appears to be commonly activated among all executive functioning processes (Shimamura, 2000). Many of the processes involved in executive functioning can be explained by where they are localized; for example, the left prefrontal cortex is thought to be involved in the initiation of responses and processing information that is verbal, concrete, or detailed. Alternatively, the right hemisphere of the prefrontal cortex is believed to be involved in the inhibition of responses and processing information that is visual-spatial or abstract (Lezak, Howieson, & Loring, 2004; Stuss et al., 2002).

The prefrontal cortex can be divided into three regions; (i) the dorsolateral prefrontal cortex, which is believed to be important for working memory, fluency, set shifting, planning, response inhibition, organization, reasoning, problem-solving, and abstract thinking (Cummings, 1993; Duke & Kaszniak, 2000; Ettlinger et al., 1975; Fuster, 2000; Grafman & Litvan, 1999; Jonides et al., 1993; Malloy & Richardson, 2001; Milner, 1971; Stuss et al., 2000), (ii) the orbitofrontal prefrontal cortex, which is believed to be important for processes such as social appropriateness, inhibition, and impulsivity (Alvarez & Emory, 2006; Blumer & Benson, 1975; Cummings, 1995), and (iii) the ventromedial prefrontal cortex, which is believed to be important for motivation, inhibition, social appropriateness, and being sensitive to rewards and/or punishments (Alvarez & Emory, 2006; Angrilli, Palomba, Cantagallo, Maietti, & Stegagno, 2004; Mathiesen, Farster, & Svendsen, 2004; Tremblay & Schultz, 2000).

Development of Executive Functioning

The development of executive functions varies widely across the lifespan, due, in part, to the developmental trajectory of the neural circuitry within the prefrontal cortex

(Shimamura, 2000). As a result, the prefrontal cortex is among one of the last brain regions to develop, and does not reach full maturation until adulthood (Best, Miller, & Jones, 2009; Gogtay et al., 2004). Therefore, executive functions are believed to begin developing in infancy, when activation in the prefrontal cortex is first observed, and continue into adulthood (Anderson, 2002; Bell & Fox, 1992; Huizinga, Dolan, & van der Molen, 2006). There is also variation in when processes first emerge and the amount of time they require until they are considered fully developed, which helps explain why processes have varying developmental trajectories and emerge at different ages (Anderson, 2002). To further complicate the development of executive functioning during childhood, there are also individual differences in how these processes develop (Miyake & Friedman, 2012).

Birth to preschool. Although it is still debated whether executive functions develop in a stage-like or gradual manner (Anderson, Jacobs, & Anderson, 2008), gains are often made by the time children are in preschool. Improvements in self-control, and ability to manage thoughts, emotions, and behavior can be observed across this developmental period (Zelazo & Muller, 2002). Many processes emerge during this initial stage of development. For example, there is a shift around age four in the ability to plan and organize activities in advance and in conceptual reasoning (Welsh et al., 1991). Improvements are also observed in attentional control throughout early childhood. For example, infants typically begin inhibiting previously learned responses for a new response set around 12 months and can begin inhibiting instinctive responses by age three (Diamond & Goldman-Rakic, 1989; Diamond & Taylor, 1996; Epsy, 1997). It has also been observed that response speed and verbal fluency significantly improve between ages three and five (Epsy, 1997; Gerstadt, Hong, & Diamond, 1994; Welsh et al., 1991). Cognitive flexibility, however, is still difficult for children prior to preschool, with perseveration errors (i.e., the repetition of an incorrect response) being very common at this age. Typically children between the ages three and four can begin switching between two response sets, but only when the decision rule is simple (Epsy, 1997; Levein et al., 1991; Welsh et al., 1991). These newly acquired abilities likely contribute to the social and cognitive development that is also observed during this time (Carlson, 2005).

Preschool to late childhood.A second important phase of development occurs by late childhood. This period is marked by a significant change in cortical gray matter development in the frontal lobes, followed by a period of pruning, which allows greater neural connectivity (i.e., faster and more efficient connections between neurotransmitters) within the frontal lobe (Anderson, 2002; Anderson et al., 2008; Scahill, Frost, Jenkins, Whitwell, & Rossor, 2003). As a result of this development, a major development in executive functioning has been observed between the ages 8 and 10, and includes improvements in attention, set shifting, and response inhibition (Klimkeit et al., 2004). More specifically, improvements have been observed in speed and accuracy for impulse control tasks around age six (Diamond & Taylor, 1996). Processing speed also improves greatly during middle childhood, with specific gains emerging between 9-10 years and 11-12 years (Anderson et al., 2000; Welsh et al., 1991).

The ability to switch between response sets, even when the decision rule is complex, improves greatly between seven and nine years (Anderson et al., 2000). This switching fluency continues to develop until adolescence (Anderson et al., 2000). There is also an improvement in the ability to learn from mistakes and develop alternative strategies during this developmental period (Anderson, 2002). Anderson et al. (2001) observed that children aged 12 to 13 prefer overly cautious strategies, despite the use of more efficient strategies at earlier ages. Finally, rapid changes in the ability to plan and organize emerge by 7 and 10 years of age, with gradual improvements continuing into adolescence (Anderson et al., 1996).

Adolescence to adulthood. Other executive functions, such as working memory and strategic planning, are thought to develop later in adolescence (Anderson et al., 2008). However, this development period is also important for many of the processes that have emerged earlier in childhood (i.e., information processing, efficiency, fluency, switching fluency, goal setting), which continue to consolidate during this time (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Anderson et al., 2000). As such, many processes are not considered to be fully developed until the end of this developmental period (Anderson, 2002). The consolidation of many processes during this time may be the result of changes in the brain that occur following puberty; insulating layers of myelin surround neurons resulting in an increase in the speed of transmission between neurons by as much as one hundred times (Blakemore & Choudhury, 2006). Therefore, it is likely that pre-existing functions become more efficient during this time because of this improved neurotransmission.

Sex differences across development. For the most part, research suggests that girls and boys exhibit a similar pattern of development across executive functioning processes (Anderson, 2002. Although some differences have been observed, they have not been shown consistently. Specifically, girls tend to outperform boys on tasks involving verbal fluency, information processing, and spatial organization, whereas boys tend to outperform girls on tasks that require spatial reasoning and working memory (Anderson, 2002; Anderson, Anderson, Northam, & Taylor, 2000; Karapetsas & Vlachos, 1997; Krikorian & Bartok, 1998).

Importance of Executive Functioning Within a School Setting

Research suggests that executive functioning plays a substantial role in learning (Bull, Johnson, & Roy, 1999; Bull & Scerif, 2001; McLean & Hitch, 1999). This appears to extend to academic performance as well; executive functioning is correlated with school readiness among preschool students (Riggs, Blair, & Greenberg, 2003) and academic achievement in older students (Diamantopoulou, Rydell, Thorell, & Bohlin, 2007). Importantly, this academic achievement is observed in mathematics (Espy et al., 2004; Gathercole, Pickering, Knight, & Stegman, 2004; McClelland et al., 2007; Passolugnhi & Siegel, 2001), literacy (Helland & Asbjøornsen, 2000; McClelland et al., 2007; Swanson, 1999), and vocabulary development (McClelland et al., 2007), skills that are critical for academic success. Importantly, the gap in academic achievement between those with and without executive functioning deficits becomes larger over time (Diamond & Lee, 2011).

Early executive functioning also appears to be predictive of academic achievement over time. Epsy and Wiebe (2008) conducted a study to examine whether the short-term memory, working memory, and executive functioning of preschoolers were predictive of academic achievement in grade three. Children were first assessed using measures of cognitive abilities, memory, and standardized, norm-referenced measures of reading and mathematics at the beginning of Kindergarten and the end of grades one and three. The executive functioning tasks (i.e., measures of attentional control, shifting, inhibition, planning, problem-solving) were the best predictors of academic achievement, with children who performed better on these tasks being more likely to perform better on tasks assessing math and reading. These gains were also maintained over the three years.

Certain executive functions appear to be related to specific areas of academic success, even after controlling for other explanatory variables, such as long-term memory retrieval, phonological processing, and processing speed (Bull, Johnston, & Roy, 1999; Gathercole & Pickering, 2000a, 2000b; McLean & Hitch, 1999; Ozonoff & Jensen, 1999). For example, mathematical ability, early numeracy, and counting skills are significantly related to performance on tasks assessing inhibition, set-shifting, planning, working memory, and attentional switching (Bull & Scerif, 2001; Kroesbergen, Van Luit, Van Lieshout, Van Loosbroek, & Van de Rijt, 2009). Reading tasks appear to be related to abilities in inhibition, attentional switching, and working memory (Altemeier, Abbott, & Berninger, 2008; Cain, Oakhill, & Bryant, 2004). Further, more complex executive functioning tasks (e.g., tasks that involve several components that require coordination) appear to be more associated with applied math problem-solving, but not with math calculations (Best, Miller, & Naglieri, 2011), but response inhibition was predictive of math calculations and phonological decoding (Mazzocco & Kover, 2007).

Interestingly, executive functioning skills can predict academic performance in very young children. Lan, Legare, Ponitz, Li, and Morrison (2011) conducted a study that assessed preschoolers using a battery of measures assessing inhibition, working memory, and attentional control along with academic achievement measures for reading and mathematics. Findings revealed individual executive functioning processes were uniquely predictive of certain academic tasks. For example, inhibition and working memory were uniquely predictive of counting and math calculations, whereas attentional control was predictive of reading and math calculations. As a result, it has been suggested that executive functioning measures can be used as early identification tools to identify children suspected of developing learning difficulties (Bull & Scerif, 2001; Kroesbergen et al., 2009).

Children with impaired executive functioning and working memory likely make errors in learning activities as a result of their difficulties with remembering directions, carrying out instructions, inhibiting irrelevant stimuli, remaining focused, and planning and monitoring throughout a task (Best et al., 2009). Based on this assumption, Gathercole et al. (2006) argued that these children are missing important learning opportunities, and therefore are also missing the necessary opportunities to practice and develop academic skills, which can keep them even further behind. As an example, one longitudinal study found that attentional difficulties at age five, as reported by parents and teachers, were strongly and negatively predictive of IQ at age 12 (Polderman et al., 2006).Therefore, early reports of executive dysfunction appear to be predictive of broad cognitive ability.

Executive Functioning Impairments

Deficits in executive functioning are often observed in various clinical populations, for example, people with Attention-Deficit Hyperactivity Disorder, Antisocial Personality Disorder, Schizophrenia, Obsessive-Compulsive Disorder, Traumatic Brain Injury, and specific language impairment have all been found to have varying degrees of executive function impairment (Alvarez & Emory, 2006; Henry, Messer, Keynes, & Nash, 2012; Sergeant et al., 2002; Morgan & Lilienfeld, 2000; Nieuwenstein et al., 2001; Perry et al., 2001). However, typically developing individuals can also have difficulty with executive functioning. There are variables among typically developing individuals that are predictive of executive functioning. For example, individuals from higher socioeconomic statuses typically have more efficient executive functioning processes (Lipina et al., 2005). Similarly, children who experience an adverse upbringing (e.g., maltreatment, neglect, poverty, exposure to violence, maternal depression) are more likely to show increased inattention and an overall delay in the development of many executive functioning processes (Cicchetti, 2002; Goldsmith & Rogoff, 1997; Lenguna et al., 2007; Li-Grining, 2007). Given that executive functions are critical for performing many complex human behaviours including learning, having a breakdown in one or more of these executive functions can result in behavioural or psychiatric impairments (Goldberg & Seidman, 1991). Often these impairments can be partially explained by damage or inefficiency within any of the neurological regions involved in executive functioning (Anderson, 2002).

Interestingly, however, there appear to be clusters or patterns of deficits among certain clinical populations. Just as patterns of deficits have been identified among groups of patients with brain injuries (e.g., social and behavioural dysregulation), certain patterns have also been observed among individuals with Attention-Deficit Hyperactivity Disorder, Autism Spectrum Disorders, schizophrenia, and Alzheimer's (Barkley, 1997; Chen, Sultzer, Hinkin, Mahler, & Cummings, 1998; Green, 1996; Pennington & Ozonoff, 1996; Russell, 1997). The majority of research examining the executive functioning of clinical populations has attempted to create executive profiles of various neurodevelopmental and psychiatric disorders (Ozonoff and Jensen; 1999). The executive profiles for Attention-Deficit Hyperactivity Disorder and Autism Spectrum Disorder, two disorders that have onset in children, are presented below.

Attention-Deficit Hyperactivity Disorder. As the most prevalent neurodevelopment disorder of childhood (American Psychiatric Association, 2000; Nair et al., 2006), Attention-Deficit Hyperactivity Disorder (ADHD) has received extensive research attention. According to a model of executive dysfunction proposed by Barkley (1997), there is a pattern of executive functioning impairment often observed among individuals with ADHD; typically this includes deficits in sustained attention, divided attention, planning, self-regulation, and working memory (American Psychiatric Association, 2000; Barkley, 1997; Nair et al., 2006; Pasini, Paloscia, Allessandrelli, Porfirio, & Curatolo, 2007; Semrud-Clikeman, Pliszka, & Liotti, 2008; Sergeant, Geurts, & Oosterlaan, 2002).

This view is also supported by research findings; for example, children with ADHD make significantly more errors on the Color-Word Test in comparison to controls and children with other neurodevelopmental disorders, indicating difficulty with inhibiting responses (Ozonoff & Jensen, 1999). Based on Barkley's proposed model of ADHD (Barkley, 1997), the deficit in inhibition commonly observed among children with ADHD depends on the effective executive functioning of four other neuropsychological processes, which include working memory, self-regulation, internalization of speech (i.e., the silent speech an individual engages in to debate a course of action and plan future activities), and reconstitution (i.e., behavioual analysis and synthesis).

Co-morbidity also needs to be considered when conceptualizing patterns of impairment, as ADHD is often co-morbid with other disorders associated with executive functioning impairment. For example, a study conducted by Willcutt et al. (2001) found different profiles of executive dysfunction among children with ADHD, reading disabilities, and those who presented with both disorders. Specifically, they found children with ADHD were more likely to have impairment in inhibition, those with reading disabilities were most likely to have impairment in working memory, and those that presented with both disorders had a pattern of impairment in inhibition, working memory, and shifting.

Autism Spectrum Disorders. Studies have consistently found that individuals with Autism Spectrum Disorders across all ages (i.e., preschoolers to adults) show deficits in planning, cognitive flexibility, and working memory (Hill, 2004; Ozonoff, 1997; Pascualvaca, Fantie, Papageorgiou, & Mirsky, 1998; Russell,1997; Shu, Lung, Tien, & Chen, 2001; Turner, 1999; Ozonoff & Strayer, 2001; Verte, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006). Ozonoff and Jensen (1999) found children with Autism Spectrum Disorders made more errors on the Wisconsin Card Sorting Test and the Tower of Hanoi task, measures of cognitive flexibility and planning. Studies consistently show, however, that individuals with Autism Spectrum Disorders do not exhibit deficit in response inhibition, as do children with ADHD (Schmitz et al., 2006). Similarly, on a study that examined parental report based on the Behaviour Rating Inventory of Executive Functioning, individuals with Autism Spectrum Disorders showed global executive functioning impairments, with the greatest deficits being flexibility and organization (Kenworthy et al., 2005).

Assessing Executive Functioning

Given executive functioning is the result of various inter-connected regions within the brain, with different processes being linked to activation in different regions, it is difficult, if not impossible, to obtain a single, pure measure of executive functioning. Although many measures have been developed to assess executive functioning, research studies frequently attempt to assess executive functioning using one or few measures (Miyake et al., 2000). Many of the measures developed to assess executive functioning are found to have a moderate correlation across measures, however, each typically contributes unique variance as well (Miyake et al., 2000). Some of the most common measures of executive functioning, as well as overall issues with using measures of executive functioning are presented below.

Wisconsin Card Sorting Test. The Wisconsin Card Sorting Test, one of the most widely used experimental measures of executive functioning, is designed to measure set shifting (i.e., the ability to be flexible with mental sets in response to goals that change over time; Eling, Derckx, & Maes, 2008). Originally developed by Grant and Berg (1948), this task typically presents participants with a target card and four sorting decks, which differ with respect to the shapes, colour of shapes, or number of shapes on each card. Participants are instructed to begin sorting the target deck and are told that the sorting rule (i.e., the correct way to sort the deck) will sporadically change, but they are not told when it will change. Although it is possible to derive various score on this task, researchers are often interested in the number of perseveration errors (i.e., continuing to sort the cards according to the previous sorting rule, despite having changed to a new sorting rule) that a participant makes.

Stroop test.A measure of inhibition and selective attention, the Stroop test is a commonly used and extensively studied research tool (Carter, Mintun, & Cohen, 1995; Stuss, Floden, Alexander, Levine, & Katz; 2001). To be successful on this task, participants require the ability to inhibit an automatic, well-learned response and instead attend to stimuli based on a decision rule (Leung et al., 2000). Participants are typically presented with various conditions, which require them to read the names of colours (e.g., “blue” presented in black or blue ink), name colours (e.g., say “red” when presented with a red square), or name an incongruent colour (e.g., say “green” when presented with the word “blue” that is presented in green ink; Leung et al., 2000). The difference in the response time between congruent (e.g., non-competing stimuli) and incongruent (e.g., competing stimuli) conditions, where there is an increased response time for incongruent stimuli, is known as the “Stroop effect” or the “interference effect” (Alvarez & Emory, 2006). Among typically developing individuals, the Stroop effect can result in an increase as high as 74% in response time (Stroop, 1935).

Continuous Performance Test (CPT). The CPT is considered to be the most widely used measure of attention in both practice and research settings (Riccio, Reynolds, Lowe, & Moore, 2002). Initially developed by Rosvold, Mirsky, Sarason, Bransome, and Beck (1956), the CPT continues to primarily be a measure of sustained attention (i.e., the ability to attend over an extended period of time) and impulsivity. Current versions of this test require individuals to differentiate between a target stimulus (i.e., number, letter, picture of an object/person) on a computer, by pressing a key when the target stimulus (e.g., the letter X) appeared on a computer screen, and inhibiting a response when another stimulus (e.g., any letter besides X) is presented (Riccio et al., 2002).

Test of Everyday Attention for Children (TEA-Ch). The TEA-Ch, designed by Manly et al. (2001), is a test of various attentional processes designed for children aged 6 to 16. One advantage of the TEA-Ch is that it recognizes that attention is not a unitary process, as different neuroanatomical regions influence the functioning of each individual attentional process (Manly et al., 2001). Therefore, in an attempt to measure attention in a variety of ways, this test is comprised of nine subtests that together give an estimate of sustained attention, selective attention (i.e., the ability to choose what to attend to and what to ignore), attention control (i.e., the ability to shift between mental sets), and divided attention (i.e., the ability to attend to multiple stimuli at one time; Manly et al., 2001).

Behaviour Rating Inventory of Executive Function (BRIEF). The BRIEF is a behavioural questionnaire that offers a rating of executive functioning during everyday tasks (e.g., classroom behaviour). Completed by a parent or teacher, a child’s executive functioning abilities within home and school environments are rated (Gioia, Isquith, Guy, & Kenworthy, 2000). The specific scales on the BRIEF include Inhibit, Initiate, Working Memory, Plan/Organize, Organization of Materials, Monitor, Shift, and Emotional Control (Gioia et al., 2000). Given children are rated on their ability to function on everyday tasks, this measure has been considered to be more ecologically valid than many experimental measures.

Difficulties with measuring executive functioning

Research has found that performance on standardized measures of executive functioning is often inconsistent with ratings of everyday executive functioning ability (Amieva, Phillips, Della Sala, 2003; Bogod, Mateer, & MacDonald, 2003; Wilson, 1993).

For example, a study conducted by Vriezen & Pigott (2002) found that parental responses on the BRIEF, a commonly used rating scale used in clinical settings, were not predictive of performance on experimental measures of executive functioning (e.g., Wisconsin Card Sorting Task, Trail Making Test, verbal fluency). It is, however, difficult to generalize across studies, as each differs in the population being examined, the measures used, and how an informant rating is obtained (e.g., parental report, teacher report, clinical report, self-report; Chaytor et al., 2006), as standardized measures account for only approximately 18-20% of variance in parent-reported executive dysfunction (Chaytor, Schmitter-Edgecombe, & Burr, 2006). In fact, research suggests that individuals who exhibit executive functioning impairments can perform exceptionally well on standardized measures of executive functioning (e.g., Wisconsin Card Sorting Task; Eslinger & Damasio, 1985; Shallice & Burgess, 1991).

Although it may seem counter-intuitive for people with executive functioning deficits to perform well on standardized measures, it has been proposed, that it is the artificial setting of standardized measures, which is not reflective of everyday abilities, that accounts for this inconsistency (Chaytor et al., 2006). That is, the simulated testing environment (e.g., artificial tasks, lack of other environmental demands, inability to use compensatory strategies, and an awareness of being observed), uncertainty surrounding the construct tapped into by each measure (i.e., systematic variance attributed to other processes), and the small sample of behaviour that is being measured (Chaytor et al., 2006; Miyake & Friedman, 2012).

Given the inconsistency between informant ratings and standardized measures of executive functioning, there has been a push to develop and use measures that show good inter-rater reliability as well as ecological validity. The Multiple Errands Test, for example, requires participants to use written instructions and grocery lists to perform tasks such as purchasing products, locating information, and arriving at destinations at certain times (Burgess, 2000). Often these ecological valid measures are difficult to administer within a clinical setting, however, resulting in a tendency to rely on standardized measures and rating scales (Chaytor et al., 2006).

Intervention to Improve Executive Functioning

Since effective executive functioning is predictive of school readiness, academic success, improved mental and physical health, and better career attainment (Blair & Razza, 2007; Dunn, 2010; Prince et al., 2007), improvement in these processes may be beneficial for those who show clear impairment. Regardless of how executive functioning is measured (e.g., observation, questionnaire, formal assessment), it is important that precautions are taken early when deficits are identified. Therefore, it will be important to devote more time and research to early identification, intervention, and accommodation for such deficits. Research is increasingly examining activities believed to improve executive functioning, with a number of studies showing promising results.

Research is increasingly examining the development of executive functioning abilities in preschoolers, as there is increased awareness that these abilities can predict later academic achievement to the same degree as other academic skills (e.g., letter recognition, phonemic awareness; Lonigan, Burgess, & Anthony, 2000; McClelland et al., 2006). A study conducted by Bierman, Nix, Greenberg, Blair, & Domitrovich (2008) examined the effects of using executive functioning processes in the design and evaluation for a school readiness program for socioeconomically disadvantaged children (i.e., Head Start). This study implemented the PATHS curriculum, a preschool curriculum designed to foster self-regulation, self-awareness, and problem solving, while establishing classroom rules and routines. Results indicated that children who attended the intervention classroom had gains in a card-sorting task (i.e., Dimensional Change Card Sort), which measured working memory, inhibitory control, and set shifting, and on a measure of task orientation measuring sustained attention and self-regulation. Subsequent improvements among the children in the intervention classroom were also observed in vocabulary, phonological sensitivity, and print knowledge, all skills that are important for academic achievement. Improvements in executive functioning processes have also been observed following programs involving computer games, meditation, attention process training, and exercise (e.g., yoga, martial arts, and aerobics; Diamond & Lee, 2011).

Computer games. Research has begun examining computer games as an opportunity to build working memory, inhibition, fluency, and attentional processing. For example, CogMed® is a computer game designed to progressively build working memory. Improvements among typically development and clinical populations (i.e., individuals with ADHD and working memory deficits) have been observed following practice with this game, gains transferred to other tasks that require working memory (e.g., tasks using mathematics), and were still present at a six-month follow-up (Holmes, Gathercole, & Dunning, 2009; Holmes et al., 2010; Klingberg et al., 2005; Thorell, Lindqvist, Bergman, Bohlin, & Klinberg, 2009). Inhibition, however, appears to be more difficult to remediate through computerized training; one study found that preschools who received training for five weeks in working memory had significant improvements following the training on both practiced and non-practiced standardized measures (e.g., spatial and verbal working memory), however, those trained in inhibition improved only on some of the practiced measures and no improvements were reported on non-practiced tasks or parent ratings (Thorell et al., 2008).

Similarly, another study conducted by Zickefoose, Hux, Brown, and Wulf (2013) examined whether brain games (e.g., attention-process training-3 and Lumosity™) improved the attention of adults with severe traumatic brain injury (TBI). Results revealed that while gains were made on both measures for some participants (TEA-Ch and probe measures), improvements did not appear to generalize beyond the measures used in this study.

Martial arts and mindfulness practices. With an emphasis on self-control and discipline, martial arts present another promising opportunity for developing executive functioning processes. A study conducted by Lakes and Hoyt (2004) had students in kindergarten to grade 5 participate in either school-based Tae Kwon Do training or traditional physical education for a three month duration. Results suggested that those in the martial arts group had greater improvements on measures of cognitive and affective self-regulation, prosocial behaviour, classroom conduct, and mental math. The largest gains were among males and students in older grades (e.g., grades four and five). Similarly, mindfulness training, developing skills for focused attention and awareness that is non-judgemental (Kabat-Zinn, 2003), has also been linked to improved executive functioning processes. For example, one study conducted by Flook et al. (2010) compared children who participated in mindfulness activities (i.e., meditation, sensory awareness, attention regulation, and awareness of others) to children who read silently;

those who participated in the mindfulness activities had improvement on measures of shifting and monitoring.

Aerobic exercise. Aerobic exercise has been found to robustly improve overall neurocognitive functioning within the prefrontal cortex and executive functioning (Choddock, Pontifex, Hillman, & Kramer, 2011; Hillman, Erikson, & Kramer, 2008). For example, improvements in executive functioning have been observed immediately following a single episode of moderately intense aerobic exercise (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro & Tidow, 2008; Ellemberg & St. Louis-Deschenes, 2010; Hillman et al., 2009; Pesce, Crova, Cereatti, Casella, & Bellucci, 2009), and following repeatedepisodes of training (Davis et al., 2007; Pesce et al., 2009). A meta-analysis of randomized controlled trials, which was limited to studies of adults who engaged in aerobic exercise programs with at least a one month duration, suggested significant improvements in attention, memory, executive functioning, and processing speed but not in working memory (Smith et al., 2010). There is less research examining the effects on children, but some research suggests that providing recess breaks alone may be enough to improve attention. Specifically, Barros, Silver, and Stein (2009) found that children who engaged in physical play during recess were more attentive in the classroom than those without breaks. Among children with Attention-Deficit Hyperactivity Disorder, physical activity resulted in significant improvements in both cognition and attention deficits, regardless of whether they were using methylphenidate (Medina et al., 2010). Despite limited research examining the relationship between physical activity and executive functioning among typically developing children, aerobic exercise, as a possible intervention, is promising because it can be inexpensive and accessible to all socioeconomic groups.

Conclusion

Executive functioning is fundamental for the successful completion of many tasks required in everyday life. Certain populations, however, tend to have impairments in one or more executive functioning processes. As such, interventions designed to improve executive functioning processes can serve an important role, perhaps most importantly for children who experience academic difficulties as a result of executive dysfunction. It is important that future research continue to examine how interventions shown to effectively improve executive functioning, such as physical exercise, can be implemented into the daily routines of children.

CHAPTER TWO

The Effect of Acute Exercise on Attentional Processes in Typically Developing Childrenand Youth

Executive functions are a cluster of higher-order cognitive processes that enablea person to effectively and efficiently perform goal-directed tasks(Berlin, Bohlin, & Rydell, 2003).Although they begin developing in infancy, executive functions continue to develop well into adulthood. (Anderson, 2002; Huizinga, Dolan, van der Molen, 2006). Executive functions are typically considered to comprise the domains of attention (e.g., selective attention, sustained attention, self-regulation, self-monitoring, inhibition), information processing (e.g., memory, processing speed), cognitive flexibility (e.g., working memory, divided attention, shifting, re-strategizing based on previous experiences), and goal setting (e.g., initiative, conceptual reasoning, planning, strategic organization; Anderson, 2002; Alexander & Stuss, 2000).

Executive functions are difficult to measure, especially in isolation. This can be partly attributed to the fact that executive functions often rely heavily on the efficient functioning of other executive functions (Alexander & Stuss, 2000) and that standardized measures are often inconsistent with qualitative reports of executive functioning (Vriezen & Pigott, 2002). For example, persons with established impairment in executive functioning (i.e., Traumatic Brain Injury to the prefrontal cortex) have been found to be successful on many standardized measures of executive functioning (Eslinger & Damasio, 1985; Shallice & Burgess, 1991). For these reasons, obtaining a valid and puremeasure of executive functioning is difficult.

One reason researchers and clinicians attempt to measure executive functioning is because these processes are considered to be especially important for success in the school setting, as they have been found to be predictive of academic achievement. Specifically, students with more efficient executive functioning processes are more likely to have better-developed skills in mathematics (Espy et al., 2004; Gathercole, Pickering, Knight, & Stegman, 2004; Passolughi & Siegel, 2001), literacy (Helland & Asbjøornsen, 2000; Swanson, 1999), and vocabulary (McClelland et al., 2007). Of the various executive functions, attention has often been the focus of research investigating the relation between executive functioning and school success. Attention can be defined as a person’s capacity to process information that is limited by the number, duration, or type of tasks a person is perceiving (Schmidt, 1988). Attention has been found to be particularly important for school success, as all academic tasks require a certain degree of attention (NICHD Early Child Care Research Network, 2003) and a poor ability to sustain attention has been found to be consistently associated with poor academic performance (Gaub & Carlson, 1997; Rabiner & Coie, 2000; Rebok et al., 1997). Given that 10-15% of the general population experience clinically significant attentional difficulties (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991), a large proportion of students are potentially at risk for academic failure or underachievement. Further, if these symptoms are unrecognized and unmanaged, affected children are at even greater risk for academic difficulties (Rabiner & Coie, 2000). Parents commonly choose not to have their children medicated, or have difficulty finding an appropriate medication/dosage for their child that does not result in undesirable side effects (Gapin et al., 2011).

Attention is not a single cognitive process (Manly, Robertson, Anderson, & Nimmo-Smith, 1999). Rather, attention can be further divided into several processes; first, selective attention is the ability to manage distraction (Posner & Peterson, 1990; Stevens & Bavelier, 2012), which is important when students are expected to remain focused in a noisy environment or when presented with irrelevant information (Stevens & Bavelier, 2012). Second, divided attention, the ability to attend to multiple stimuli at one time (Posner & Peterson, 1990), is important for tasks such as copying notes and attending to a teacher simultaneously. Third, sustained attention, the ability to maintain attention over an extended period of time (Posner & Peterson, 1990), is important when the student must remain focused on a lengthy test or assignment. Finally, attentional control/switching is the ability to choose which stimuli to attend and which to ignore (Posner & Peterson, 1990). This is important for tasks such as switching between mathematical operations in a single test item.

Within a school setting, attentional difficulties can translate into making careless mistakes and experiencing difficulties in a number of areas such as understanding academic tasks, transitioning between activities,performing when presented with multiple stimuli or abundance of detail, and applying novel strategies when task demands change (Flanagan, Ortiz, & Alfonso, 2013). More specifically, studentswith attentional difficulties commonly make errors and underperform in reading (e.g., frequentlylosingtheir place, missing important details), writing (e.g., difficulty completing long assignments, difficulty adhering to time lines), and math (e.g., inability to attend to math signs, difficulty attending to relevant information in word problems; Flanagan et al., 2013; Merrell& Tymms, 2001). Given findings suggesting that attentional difficulties prevent students from reaching their potential, it is important to examine and evaluate school-based interventions that can help improve weak executive function processes, particularly attention.

Intervention for Executive Functioning Deficits

Early identification and intervention of executive dysfunction is important, as the disparity in academic achievement between those with and without executive functioning deficits becomes larger over time (Diamond & Lee, 2011). A variety of interventions are hypothesized to improve inattention, including exercise, computerized games, meditation, and attention process training (Diamond & Lee, 2011). Exercise is a particularly promising intervention because it can be easily and inexpensively implemented within a school setting; because exercise is amenable to a school setting, it can be offered to a wide-range of students who may derive benefits such as increased ability to attend in the classroom (MacKelvie, Khan, Petit, Janssen, & McKay, 2003). Acute aerobic exercise (i.e., exercise that is moderately intense and short in duration) may be especially useful within a school setting, given that it can be easily incorporated into recess and physical education classes (Janssen & LeBlanc, 2010).

Recently, there has been an increase in research examining the effects of physical activity on cognitive processes in children (Trudeau & Shephard, 2009). Although studies have generally found that physical activity leads to improvements in some cognitive processes such as inhibitory control, attention, processing speed, memory, and overall cognitive performance (e.g., Hillman et al., 2006; Sibley & Etnier, 2003; Strong et al., 2005; Smith et al., 2010), findings are somewhat inconsistent with respect to the degree of improvement and the specific processes believed to benefit from this type of intervention (Berwid & Halperin, 2012; Pontifex et al., 2011). These inconsistencies are likely the result of methodological differences between studies (e.g., intensity, type, and duration of exercise, processes being measured, measures used; Berwid & Halperin, 2012). Further, it is also difficult to determine which processes benefit from physical activity, as most studies examine a variety of executive functioning processes. Therefore, given that research specifically investigating attention is limited, a review of studies examining attention as apart of a broader investigation of executive functioning will be reviewed here.

In a study that examined attention and inhibitory control in children between the ages of 6 and 10 years (Best, 2012), participants either engaged in a single session of high physical activity (i.e., 20 minutes of moderately-intense cardiovascular exercise) or low physical activity (i.e., 20 minutes of sedentary video games or movies), each using the Nintendo Wii. Following each session, participants completed the Attention Network Task (ANT), a computerized version of the flanker task that measures response inhibition, information processing, and selective attention. Results indicated that children in the high exercise group showed improvements on the ANT as compared to children in the control group. Interestingly, this study also examined the effects of cognitive engagement, where participants in the “high physical activity, low cognitive engagement” were instructed to run as far as possible for 10 minutes, and those in the “high physical activity, high cognitive engagement” group were instead instructed to perform various games that required physical activity. Although all participants who engaged in the high physical activity groups performed significantly better on the ANT than those in the low physical activity groups (i.e., watching a video, playing video games), no differences were observed between the high and low cognitive engagement groups. This finding suggests that it is the intensity of the physical activity, rather than the type of physical activity or cognitive engagement, that is more important for improved executive functioning.

In a study conducted by Ellemberg & St. Louis Deschenes (2010), 7 and 10 year old boys were randomly assigned to either a physical activity condition (i.e., 30 minutes of cycling and 10 minutes of warm up/cool down) or a control condition (i.e., 40 minutes watching a popular television show). They were assessed before and after the intervention on a series of simple reaction time and decision-making tasks, including detection of a shape on a computer screen (i.e., response activation) and detecting a target shape on a computer screen (i.e., response selection, and sustained attention). Results found that participants who engaged in the physical activity had quicker response times, but had similar accuracy, in comparison to those who did not engage in the exercise. Overall, findings suggest that there are some improvements associated with physical activity, which do not appear to impact children differentially based on their age.

Improvements in executive functioning have also been observed in studies examining longer sessions of physical activity. For example, Fisher et al. (2011) examined whether boys between the ages of five and six years who engaged in two hours of intense physical exercise per week for 10 weeks would show improvements on measures of planning, attention, perceptual processing, and memory (i.e., Attention Network Test [ANT], Cognitive Assessment System [CAS], and Cambridge Neuropsychological Test Battery [CANTAB]) in comparison to participants who engaged in standard physical education classes at school. Findings indicated that the participants in the intense physical activity condition outperformed those in the standard physical education classes on measures of spatial working memory (CANTAB), spatial span (CANTAB), and overall accuracy (ANT). However, improvements were not found on the planning and attention measures of the CAS. Interestingly, participants in the intense physical activity group were rated by their parents as having fewer cognitive problems/inattention following the intervention, as reported on the Connor's Parent Rating Scale.

Several hypotheses have been proposed to explain the improvements in attention and other executive functions following exercise. First, improvements in attention may be attributed to the changes in brain functioning and structure that are thought to occur following exposure to physical activity, including regulation of neural development (e.g., survival, growth, and differentiation of neurons), synaptogenesis, myelination, and angiogenesis (for a more in-depth review of structural changes, see Berwid & Halperin, 2012). For example, among rats and humans, a short duration of exercise was found to result in increased production of serotonin (which was associated with improved memory storage and retrieval), dopamine, and norepinephrine (which was associated with improved attention; Goekint et al., 2012; Peyrin, Pequignot, Lacour, & Fourcade, 1987; Querido & Sheel, 2007). Second, it has been suggested that the cognitive benefits associated with physical activity, specifically with respect to improvements in attention, are the result of exercise leading to heightened physiological arousal, which, in turn, allows individuals to attend more fully to a given stimulus resulting in subsequent improvements in other executive functioning tasks (Audiffren, 2009). Finally, it has also been suggested that physical activity may result in *cognitive engagement*, where higher order cognitive processes become engaged (Best, 2010). Although less established in the literature, some studies have shown that physical activity that includes a component of cognitive engagement (e.g., sports) results in greater improvement among executive functions (Budde, Voelcker-Rehage, Pietrabkyl-Kendziorra, Riberio, & Tidow, 2008; Pesce et al., 2009).

Clinical Applications

Research has shown that exercise can result in improved attention in children with Attention Deficit Hyperactivity Disorder (ADHD; Berwid & Halperin, 2012), a neurodevelopmental disorder characterized by a pattern of executive functioning deficits, such as inattention (American Psychiatric Association, 2000; Barkley, 1997; Nair et al., 2006). Specifically, exercise may be particularly useful as an intervention in this population, as it has been proposed that the symptoms of ADHD can be partially attributed to poor regulation of dopamine(Bandessarini, 1997) and exercise has been shown to increase the availability of dopamine in the brain regions implicated in ADHD (Hattori, Naoi, & Nishino, 1994). Again, research specifically examining the effect of exercise on attention in this population is limited. Chang, Liu, Yu, & Lee (2012) examined the effects of 30 minutes of moderately intense physical activity on overall executive functioning in a sample of children with ADHD between the ages 8 and 13. Results revealed that participants who engaged in the physical activity outperformed those in the control group on a measure of selective attention and cognitive inhibition (i.e., Stroop Colour-Word task), and on a measure of attentional shifting (i.e., the Non-Pervasive Errors measure of the Wisconsin Card Sorting Task). Research has also found that children with ADHD who are more physically active, as assessed by an accelerometer, performed better on tasks measuring executive functioning (e.g., planning, inhibition, working memory, processing speed) than children who are not physically active (Gapin & Etnier, 2010). Results such as these highlight the benefits of even moderate levels of physical exercise for children with ADHD. Despite the promising results that exercise can improve attention in clinical and typically developing populations, many research questions remain unanswered. Given research has found cognitive improvements, including in attentional processes, following various exercise interventions in both clinical populations (Berwid & Halperin, 2012; Chang et al., 2012; Gapin & Etnier, 2010) and typically developing children and adolescents (Best, 2010; Ellemberg & St. Louis Deschenes, 2010; Fisher et al., 2011), it is important to conduct a more thorough examination of the effects of physical activity on attention in typically developing children and youth. This can inform management of students with sub-clinical or untreated symptoms of inattention and can also provide a baseline for clinical research. It is also important to conduct more thorough examinations of the executive functioning processes implicated; attention, for example, has often been left out in favour of other cognitive processes, and when it is examined, measures that assess multiple processes are often used, making it difficult to gauge the effect on attention alone(Chang et al., 2012; Gapin & Etnier, 2010; Medina et al., 2010). A related criticism of previous research is that attention has been examined using one or few measures (Chang et al., 2012; Gapin & Etnier, 2010; Medina et al., 2010; Miyake et al., 2000). Given the complexity of attention, which is a central process that can only be assessed if other processes (e.g., perceptual, cognitive) are also activated (Manly et al., 2001), it would be useful to assess a variety of attentional processes. Understanding the effect of acute exercise on various attentional processes is an important preliminary step in developing recommendations for school-based behavioural interventions for students who experience inattention.

Present Study

This study will examine the effects of acute physical activity across multiple attentional processes (i.e., selective attention, divided attention, sustained attention, and attentional control/switching) in typically developing children and adolescents. Based on previous findings, it is expected that children who engage in 30 minutes of acute physical activity will show improvements in attention, which will be differential across all attentional processes, compared to those who do not engage in the physical activity intervention. The findings of this study will inform the literature in three important ways. First, by examining multiple attentional processes, this study will offer insight into whether acute exercise differentially affects these processes. Second, this study will extend previous findings by clarifying the optimal learning and assessment conditions of typically developing children (e.g., improved performance on challenging tasks after recess or gym class), especially in children who exhibit inattention (e.g., younger students, students from lower socioeconomic areas, students with neurodevelopmental disorders). Finally, understanding the benefits of acute exercise on attentional processesin typically developing children could also informthe literature with respect to behavioural management of disorders such as ADHD. By establishing a baseline, this information can be used to understand attentional abnormalities in children with ADHD and to speculate about the attentional processes that will benefit the most from exercise. Importantly, findings of the proposed study will allow clinicians to provide more streamlined recommendations for managing cognitive symptoms of inattention in settings in which these cognitive processes are especially important (e.g., school).

Method

Participants

Participants were 26 children and adolescents (11 males, 15 females) aged 10-13 years (*M* = 12.4, *SD* = 1.4), who were randomly assigned into either a control or experimental group. Demographic characteristics of the sample can be found in Table 1. To recruit participants, advertisements (e.g., posters, online) were used throughout Halifax, Nova Scotia. To be eligible for this study, participants had to be typically developing (i.e., absence of a clinical disorder such as ADHD or Autism Spectrum Disorder), be capable of engaging in physical activity (i.e., absence of medical restrictions, no known impairing health conditions), speak English as a primary language, have normal or corrected-to-normal vision, and refrain from engaging physical activity on the day of testing. For participants' in the exercise condition to be included in the final analyses, they were required to engage in exercise that was considered to be vigorously intense (i.e., VO_2max of > 60%; see pp. 36-27 for a description). All participants achieved a VO_2max of greater than 60% (*M* = 88.3, *SD =6.8*).

Materials

Physical Activity Readiness Questionnaire for Everyone (PAR-Q+; Canadian Society for Exercise Physiology, 2012**)**.Participants and their parent/guardian completed this questionnaire. The PAR-Q was used to gather information about health conditions and readiness to partake in physical activity(Appendix B). For example, questions include "has your doctor ever said that you have a heart condition OR high blood pressure?" and "are you currently taking prescribed medication for a chronic medical condition?" Permission to use this questionnaire was granted by the authors (M. Duggan, personal communication, September 23, 2013). To be included in the final analyses, parents of participants needed to respond “no” to all questions.

Demographic and History Questionnaire. A parent-report demographic questionnaire was used to gather general information, such as age, sex, race, family composition, and medical history (Appendix A).

Digit Span (Wechsler Intelligence Scale for Children, Fourth Edition; Wechsler, 2003). The Digit Span subtest of the WISC-IVwas used to assess working memory and attention, as it has been found to be a significant predictor of attention (Groth-Marnat & Baker, 2003), Participants wereread a series of numbers at a rate of one per second. They were then asked to repeat the series inboth forward and backward sequence. Standard scores were obtained by calculating the number of sequences the participant was able to repeat correctly.

Letter-Number Sequencing (Wechsler Intelligence Scale for Children, Fourth Edition; Wechsler, 2003). The Letter Number Sequencing subtest of the WISC-IV was also used to assess working memory and attention. The examiner read a series of letters and numbers at a rate of one per second. Participants were asked to recall the numbers in ascending order and the letters in alphabetical order. Standard scores were obtained by examining the number of sequences the participant was able to repeat correctly.

Heart rate monitor. Heart rate (HR) was measured with a Pyle Sport Heart Rate Monitor (PHRM38GR). This device monitored the participant’s heart rate, measured in beats per minute, and the maximum beats-per-minute was recorded. This was used to obtain an estimate of the workout intensity. Intensity was estimated by converting the average maximum HR across all three exercise activities and converting it into a percentage of maximal HR (VO_2max), where maximal HR is estimated by the formula 206.7- (0.67 x age) (Gellish et al., 2007).To be included in the final analyses, participants were required to engage in exercise that was at least vigorously intense, defined as being > 60% of maximal HR (Thompson et al., 2003). All participants achieved a VO_2max of greater than 60% and were included in the final analyses.

Exercise equipment. Gym equipment from Cole Harbour Place, a fitness facility in Cole Harbour, Nova Scotia, was used. Specifically, equipment included the Cybex 625AT Total Body Arc Trainer, Cybex 770T Treadmill, and Cybex 525C Upright Bike (Cybex International, Medway, MA).

Exercise Video. Participants assigned to the control condition watched “Kidzercize”, a 9-minute exercise video created for children (Mayberry, 2010).

Questionnaire of Perceived Exertion. Modeled after a rating of perceived exertion (Borg, 1998), this self-report questionnaire required participants in the exercise condition rate their perceived level of physical exertion on a 10-point Likert scale (1 = minimal exertion; 10 = maximum exertion) (Appendix C).

Test of Everyday Attention for Children (TEA-Ch; Manly et al., 1999). The TEA-Ch is a multi-faceted measure of attention, modeled after several validated tests (e.g., Wisconsin Card Sorting Test, Stroop task; Manly et al., 1999), that includes measures of sustained attention, selective attention, divided attention, and attentional control/shifting. This test has been found to be both valid and reliable, with test-retest reliability for the four measures included in this study (described in more detail below)rangingfrom .71 and .81 (Manly et al., 1999).

The full battery of the TEA-Ch was not administered, due to time constraints. Instead, a screening version was used, as recommended by Manly et al.(1999). The screening version of the TEA-Ch consists of four subtests: (1) Score! (sustained attention); (2) Sky Search (selective attention); (3) Sky Search DT (divided attention); and (4) Creature Counting (attentional control/switching).

Procedure

Participants and a parent/guardian completed the experimental protocol at a local fitness facility on a day that the participant had not already engaged in physical activity. Following the informed consent and assent process, participants were asked to complete the PAR-Q to ensure that they are deemed physically fit and capable of performing all tasks in this study (i.e., responded “no” to all questions). While the parent/guardian completed the demographics questionnaires,participants were randomly assigned to the exercise (i.e., 30-minutes of moderately intense exercise) or control condition (i.e., asked to engage in 30-minutes of non-exercise tasks). Prior to beginning each condition, all participants were asked to complete Digit Span and Letter-Number Sequencing from the WISC-IV.

Participants assigned to the exercise condition were instructed to “try to do the best workout possible”. They were asked to warm up for two minutes, spend 30 minutes on cardio equipment (i.e., 10 minutes each on the treadmill, bike, and arc trainer), and cool down for two minutes. In contrast, those assigned to the control condition spent 30 minutes engaging in exercise related tasks (i.e., walking tour of the fitness facility, watching a 9-minute exercise video, and discussing the benefits of exercising).

Immediately following these tasks, participants in both groups were asked to rate their level of physical exertion and complete subtests from the TEA-Ch,as described below:

(1) Sustained Attention Subtest: Score!In this10-item counting measure, participants were asked to silently count tones without the use of fingers. At the end of each trial, participants were asked to give the total number of tones that they heard in that trial, ranging from 9 to 15. The score on this subtest was the total number of trials in which the participant provided the correct response.

(**2) Selective Attention Subtest: Sky Search.**Participants were provided with a laminated sheet of various pairs of four types of spacecraft. Participants were asked to circle all pairs of spacecraft that are identical, as quickly as possible. There are 20 matching pairs in total, and 108 non-matching pairs that were used as distractors. To ensure that this measure was not confounded by motor speed, participants were also asked to complete a motor control version of this subtest, in which distractors items were removed from the sheet. An overall score was determined by subtracting the motor-control time-per-target from the sky search time-per-target.

(3) Divided Attention Subtest: Sky Search DT. In a combination of the *Score!* and *Sky Search* subtests, participantswere asked to complete *Sky Search* (identical except for the location of target pairs), while silently counting and reporting the number of tones from the *Score!*subtest. Participants completed as many *Score!* items as it took to complete *SkySearch.* Scores from both measures were used to determine a total score. Scores included: (a) total time spent on *Sky Search* divided by the number of correctly identified pairs, and (b) total *Score!* items correctly counted divided by the total number of items attempted. An overall score will be determined by dividing (a) by (b) and subtracting the raw time-per-target score from *Sky Search.*

(4) Attentional Control/Switching Subtest: Creature Counting. Participants were presented with a Counting Creatures stimulus booklet consisting of seven trials, depicting "creatures" in their burrows, interspersed with up or down arrows between some creatures. Participants were asked to count the creatures from top to bottom, counting forward when they came to an up arrow, and counting backward when they came to a down arrow. The number of correct responses and the time spent on each trial was recorded. An overall seconds-per-switch score was calculated by dividing the time taken to successfully complete trials by the correct number of switches in those items.

Results

Sample Characteristics

All 26 participants, randomly assigned into experimental (n = 13) and control (n = 13) groups, were included in the final analyses. However, two outliers for specific subtests were removed, which resulted in a smaller control group (n = 12) for the Sky Search and Sky Search DT subtests. There were no significant differences between the groups across demographic characteristics, including ethnicity ($\chi^2(3, N = 26) = 1.71$, $p > .05$), sex ($\chi^2(1, N = 26) = .16$, $p > .05$), age ($t(24) = -.70$, $p > .05$), and average amount of time spent engaging in physical activity per week ($t(24) = .58$, $p > .05$). The demographic characteristics between both groups are described in Table 1. The groups also did not differ in their performance on Digit Span and Letter-Number Sequencing, but did differ significantly on their responses for the Questionnaire of Perceived Exertion (see Table 2).

Effect of Exercise on Attention

A one-way between-subjects multivariate analysis of variance (MANOVA) was used to assess the impact of the exercise intervention on attention, with Condition (Exercise vs. Control) as the between-subjects factor and TEA-Ch Subtests (Creature Counting, Score!, Sky Search, and Sky Search Dual Task) as dependent variables. Results indicate that the MANOVA was significant, with a statistically significant difference between groups on the combined dependent variables, F (4, 19) = 3.28, p < .05, partial η^2 = .41. Follow up Analyses of Variance (ANOVAs) for each of the dependent variables, using a Bonferroni adjusted alpha level of 0.0125, showed that groups differed significantly on the Creature Counting subtest$F$ (1, 22) = 9.33, p = .006, partial η^2 = .30, with participants in the Exercise condition exhibiting higher scores than those in the Control condition. No other significant main effects or interactions were observed. Means and standard deviations for all dependent variables are shown in Table 3.

Discussion

The present study examined the effects of a single session of vigorously intense exercise on various attentional processes in typically developing children and adolescents. Specifically, it was hypothesized that the exercise intervention would result in improved attention following the exercise intervention. It was further hypothesized that there would be differential effects across the various attentional processes. Results indicated a single session of acute, vigorously intense exercise facilitated performance on the attentional control/switching subtest (i.e., Creature Counting). Therefore, the hypothesis, that attentional processes improve following exercise, was not supported, given only one of four attentional processes were improved. However, the second hypothesis, that attentional processes would be differentially impacted, was supported. It was expected that the findings of this study would provide valuable information regarding which attentional processes benefit from vigorously intense exercise, whether this type of exercise can be used to promote optimal learning conditions for typically developing children and adolescents, and inform the use of exercise for clinical purposes. These are discussed below, in relation to the findings of the present study.

Main Findings and Study Implications

The primary finding of the present study is that a single session of vigorously intense physical activity improves attentional control/switching, but not other attentional processes (i.e., sustained attention, divided attention, selective attention). Although consistent with previous research that has found acute physical activity results in improved performance on measures of attention (Best, 2010; Ellemberg & St. Louis Deschenes, 2010), it offers a more thorough examination of how attentional processes are impacted. It has been proposed that improvement in attentional processing is the result of neurochemical changes and the physiological arousal that occur immediately following physical activity (Audiffren, 2009; Meeusen, Piacentini, & De Meirleir, 2001); these changes are thought to prime an individual for learning and improve the capacity for attending (Audiffren, 2009; Best, 2010; Winter et al., 2007). Specifically, research suggests a dose-response relationship, where shorter, more intense periods of physical activity improves learning to a greater degree than longer, less intense physical activity or periods of relaxation (Davis et al., 2007; Davis et al., 2011; Fisher et al., 2011; Winter et al., 2007).

A limitation to previous research that has shown physical activity improves attentional processes is that the measures used do not allow attention to be examined by individual attentional process (Best, 2010; Ellemberg & St. Louis Deschenes, 2010). Therefore, the specific benefit of physical activity on attention remains vague. The present study, which to our knowledge is the first to examine acute physical activity using a measure that differentiates between attentional processes, offers a more in-depth understanding of how individual attentional processes are impacted by a single session of acute, vigorously intense physical activity. Specifically, the findings of the present study show that while attentional control/switching is significantly improved following the exercise intervention, sustained, divided, and selective attention are not. Therefore, given this study was the first to systematically differentiate between attentional processes, the finding that not all attentional processes improve equally following a single session of acute exercise suggests that attentional processes are not equally sensitive to the affects of exercise.

Given attentional control/switching encompasses multiple executive functions, including inhibition, working memory, and set shifting (Preston, Heaton, McCann, Watson, & Selke, 2009), it may be that the overlap with these other executive functions, which have been found to have greatest improvements following physical activity (Tomporowski, Davis, Miller, & Naglieri, 2008; Tomporowski, Lambourne, & Okumura, 2011), can partially explain why attentional control/switching was the only attentional process to significantly improve following the exercise intervention. Therefore, although the findings of this study offer further support for previous studies that have shown improvements to attention following physical activity (Best, 2010; Ellemberg & St. Louis

Deschenes, 2010; Fisher et al., 2011), results may also be used to suggest that the effects of exercise on attention, particularly across attentional processes, may be somewhat limited.

Importantly, the finding that performance on attentional control/switching is significantly better following the exercise intervention has academic implications. A study conducted by Preston, Heaton, McCann, Watson, and Selke (2009) found that, among children with ADHD, attentional control/switching, as measured by subtests from the TEA-Ch, accounted for a significant amount of variance across all academic areas, including reading, mathematics, and spelling, even after accounting for verbal IQ (i.e., on the Wechsler Intelligence Scale for Children – Fourth Edition) and parent reported inattention. Although research has yet to examine if poor performance on measures of attentional control/switching also account for academic difficulties among typically developing children and adolescents, it stands to reason that improving the ability to flexibly and adaptively change attentional focus and inhibit automatic or irrelevant responses in favour of those that are more relevant (Anderson, 2002; Cooley & Morris, 1990) will have a positive influence across academic areas among typically developing children and adolescents as well. Therefore, the potential that 30 minutes of vigorously intense exercise can improve attentional control/switching, which may also impact academic learning, is promising.

Clinical Implications

Findings of the present study offer more support for the use of exercise interventions in clinical populations, as the benefits of exercise are thought to be most beneficial to individuals with impaired cognitive processes (Scarmeas & Stern, 2003; Whalley, Deary, Appleton, & Starr, 2004). Given current interventions for ADHD fall into either a pharmacological (e.g., stimulant medication, non-stimulant medication) or behavioural (i.e., parent management training, contingency management) classification (Berwid & Halperin, 2012), physical activity offers an alternative or conjunction treatment for symptoms of ADHD. Although behavioural and pharmacological treatments have been found to effectively manage symptoms of ADHD (Conners, 2002; Greenhill, Halperin, & Abikoff, 1999; Spencer et al., 1996), these benefits can be short-lived(Molina et al., 2009). Therefore, physical activity can be used as an effective alternative to traditional treatment methods.

Chang et al. (2012) examined acute physical activity among children with ADHD. Their findings showed improvements, following 30 minutes of moderately intense physical activity, on measures of selective attention and attentional switching. This finding differs from the findings of the present study, as the present study found significant improvements in attentional control/switching, but not for selective attention. Although some caution needs to be exerted given both studies used different measures of attention, this difference does suggest that children with ADHD may benefit to a greater degree than typically developing children and adolescents.

Impairment in attentional processes and executive functioning has been observed in various clinical populations, including people with Attention-Deficit Hyperactivity Disorder (Barkley, 1997; Sergeant, Geurts, & Oosterlaan, 2002), Autism Spectrum Disorder (Ashburner, Ziviani, & Rodger, 2010; Ozonoff, 1997; Russell, 1997), traumatic brain injury (Capruso & Levin, 2000; Mangeot, Armstrong, Colvin, Yeates, & Taylor, 2010), Antisocial Personality Disorder (Morgon & Lilienfeld, 2000), Schizophrenia (Nieuwenstein, Aleman, & deHaan, 2001; Perry, Potterat, & Braff, 2001), and Obsessive-Compulsive Disorder (Dittrich & Johansen, 2013). However, the benefit of exercise on attention in many of these clinical populations have yet to be examined (Halperin, Matier, Bedi, Sharma, & Newcorn, 1992). Given the present study found that acute physical activity benefits attentional processes in typically developing individuals, the potential impact of physical activity for many of these clinical populations is promising. This study can be used as a baseline for future research that examines these clinical populations.

Implications for Educators and School Psychologists

Importantly, the findings of the present study can inform the management of children with attentional difficulties in the classroom. Given that 10-15% of children are suspected of having significant attentional difficulties (Mirsky et al., 1991), it is important that schools be informed on the best practices for managing these students. This may be especially important for schools within lower socioeconomic areas, as executive dysfunction and attentional difficulties are more prevalent within these areas (Lipina, Martelli, Vuelta, & Colombo, 2005; Stevens, Lauinger, & Neville, 2009), with students who have experienced an adverse upbringing (e.g., maltreatment, neglect, poverty, exposure to violence, maternal depression) being at the greatest risk (Cicchetti, 2002; Goldsmith & Rogoff, 1997; Lenguna et al., 2007; Li-Grining, 2007). These students are at risk of experiencing academic difficulties, as research shows that typically developing children who experience a high degree of inattention are more likely to have lower achievement in reading and mathematics (Merrell & Tymms, 2001).

Our findings, which suggest that as little as 30 minutes of vigorous exercise can significantly improve students' overall attention, with specific improvement to their attentional control/switching, can inform management of students with attentional difficulties in three important ways. First, it will be important to advocate for additional time devoted to physical education within schools; there has been a decline in the amount of time devoted to physical education, and many children do not receive the recommended amount of physical activity(Centers for Disease Control and Presvention, 2007). Further, the time that is spent on physical education may benefit from re-structuring. Improvements in attentional processes in the present study were observed following exercise that was considered to be vigorously intense. This is consistent with previous research that has reported increased cognitive benefits associated with more intense exercise (Davis et al., 2007; Davis et al., 2011; Fisher et al., 2011). Therefore, to see the desired improvements, it may be necessary to ensure that physical education classes are promoting vigorously intense exercise. Similarly, recess and lunch have the potential to be beneficial; although they are designed to foster physical activity as well as social development (Council on School Health, 2013), and are generally considered to be an unstructured playtime, inattentive students may benefit from having more organized physical activity available during these times.

Second, when an educator has a specific concern surrounding an inattentive student, school-planning teams can consider physical activity, in addition to more commonly used management strategies (e.g., cueing to orient the student, minimizing classroom distractions, alternative seating arrangements; Stevens & Bavelier, 2012). For example, inattentive students may be given the opportunity to join in on an extra physical education class. This will be especially important prior to occasions when it is extremely important that a student is attentive, such as during to specialist assessments (e.g., psych-educational, speech language), academic testing, or when learning foundational concepts. Finally, given attention is important for language processing (e.g., attending to the boundaries between words), mathematics (e.g., attending to relevant information while performing calculations or word problems), and literacy (e.g., using appropriate scan patterns of text, attending to common letters or letter clusters; Stevens & Bavelier, 2012), physical activity may be useful for students who experience academic difficulties within a classroom. By providing an opportunity to be physically active, educators can offer students an optimal environment for learning and academic success.

Limitations and Future Direction

Given the present study is a pilot study that was intended to be an exploratory examination of exercise and attention, there are several limitations that should be considered for future research. Despite significant findings suggesting that exercise is differentially beneficial to attention, this study is limited by the small sample size (N = 26), therefore it will be important to replicate the present findings with a larger sample. A narrow age range, from 10 to 13, was also used in this study. By broadening this age range, future studies would be able to identify developmental differences in how exercise benefits attentional processing. This will be important because research suggests that attentional processes have varying developmental trajectories (Anderson, 2002).

Future studies may also wish to explore other forms of physical activity, to see whether they have the same effect. This will be important as there have been mixed findings surrounding which type of physical activity results in the greatest benefits (Colcombe & Kramer, 2003; Best, 2010). It will also be interesting to examine the “doses” of exercise required to improve attention. Among adults, studies have shown improvements in as few as five minutes of physical activity (Barton & Petty, 2010). From a classroom perspective, a shorter duration would be easier to implement during the school day. Therefore, it will be important to know, in children, how much exercise is required to see improvement, and the length of session and intensity that is associated with optimal improvement.

Caution needs to be exerted surrounding the parent reported amounts of physical activity, as the accuracy and reliability of self and parent reported physical activity has been questioned in previous studies (Gregory, Parker, & Thompson, 2012). An accelerometer may be useful to obtain a better estimate of average physical movement. Similarly, additional demographic characteristics, such as height and weight, would be useful for gauging the intensity of the physical activity, given the size of children can vary widely and therefore how much movement is required of them, can vary widely (Reed & Stuart, 1959).

Future studies may be interested in using a parent and/or teacher report of attentional capacity (e.g., Conners' 3rd Edition gives an estimate of inattention; Conners, 2008). This may further inform clinical applications, as inattention can be conceptualized as being on a continuum (Levy, Hay, McStephen, Wood, & Waldman, 1997), where children without clinical diagnoses can be rated as having elevated inattention (Merrell & Tymms, 2001). Having an estimate of inattention would allow researchers to gauge haw inattentive children and adolescents (i.e., those that score at the upper limit of the continuum) perform relative to their more attentive peers (i.e., those that score in the middle or lower limit of the continuum). Similarly, it would be interesting to compare performance of inattentive children and adolescents who do not have clinical diagnoses with children and adolescents with ADHD. This may allow researchers and school psychologists to use rating scales to predict the groups of children that will benefit the most from exercise interventions.

A final limitation to this study is the measure used to assess attention, the Test of Everyday Attention for Children (TEA-Ch). This test has been criticized for the size of the normative sample used; although they had an overall modest sample size (*N* = 293), when divided by age and sex, group sample sizes are small and unrepresentative(e.g., *N* = 13-30 per age band; Manly et al., 2001; Strauss, Sherman, & Spreen, 2006). Caution needs to be exerted when using these norms in North America, as the sample consists of children and adolescents from Australia (Manly et al., 2001; Strauss et al., 2006). Despite this limitation, however, the TEA-Ch is unique in the way that it differentially examines attention across the various processes (Strauss et al., 2006). A second limitation to the study, also applicable to the TEA-Ch, is that during the present study it was suspected that some subtests may have had ceiling effects. Although only briefly discussed in the manual, Manly et al. (2001) did specify that among adolescents in the oldest age band, 72% scored at ceiling on the Score! subtest, while 34% scored at ceiling on the Creature Counting subtest. This may partially explain the violation of the normality assumption that was observed in the present study. As such, future studies may consider finding alternate or additional measures of sustained attention and attentional control/switching. There are other measures of sustained attention and attentional control/switching on the TEA-Ch (Manly et al., 1999). Given this study found that attentional control/switching, as measured by the Creature Counting subtest from the TEA-Ch, resulted in significantly better performance among participants in the exercise intervention, future studies may benefit from also examining the second measure of attentional control/switching on the TEA-Ch, Opposite Worlds (Manly et al., 1999), to see if performance across these tasks is consistent.

Conclusion

Given that inattention exists among typically developing children and adolescents (Merrell & Tymms, 2001) and among clinical populations who are either undiagnosed or unmedicated, inattention poses a significant problem within a classroom setting. This study offers preliminary support for acute physical activity as an intervention to improve attentional control/switching, a process found to greatly impact academic outcomes (Preston et al., 2009). Given that attention plays a substantial role in learning (Gaub & Carlson, 1997; Rabiner & Coie, 2000; Rebok et al., 1997), physical activity can be used to support inattentive students in the classroom. Although exercise interventions are highly recommended, based on the results of the present study, it will be important that research continue to explore the benefits of such interventions to ensure that they are designed to be as efficacious as possible. In particular, future studies may wish to replicate the present study using a larger sample, use additional measures, collect more demographic data, and vary the exercise intervention. This study offers preliminary support for the benefits of exercise intervention on attentional control/switching; parents, teachers, and clinicians may use this information to guide the behavioural management of inattentive children and adolescents.

References

Alexander, M., & Stuss, D. (2000). Disorders of frontal lobe functioning. *Seminars in Neurology*, *20*, 427-437.

Altemeier, L. E., Abbott, R. D., & Berninger, V. W. (2008). Executive functions for reading and writing in typical literacy development and dyslexia. *Journal of Clinical and Experimental Neuropsychology*, *30*(5), 588-606.

Alvarez, J. A., & Emory, E. (2006). Executive function and the frontal lobes: A meta-analytic review. *Neuropsychology review*, *16*(1), 17-42.

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Amieva, H., Phillips, L., Della Sala, S. (2003). Behavioral dysexecutive symptoms in normal aging. *Brain and Cognition*, *53*(2), 129-132.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood.*Child Neuropsychology: A Journal of Normal and Abnormal Development in Childhood and Adolescence*, *8*(2), 71-82.

Anderson, P., Anderson, V., Northam, E., & Taylor, H. (2000). Standardization of the Contingency Naming Test for school-aged children: A new measure of reactive flexibility. *Clinical Neuropsychological Assessment*, *1*, 247-273.

Anderson, V., Jacobs, R., & Anderson, P. J. (2008). Executive functions and the frontal lobes: A lifespan perspective. New York: Taylor and Francis.

Angrilli, A., Palomba, D., Cantagallo, A., Maietti, A., & Stegagno, L. (1999). Emotional impairment after right orbitofrontal lesion in a patient without cognitive deficits. *Neuroreport*, *10*, 1741–1746.

Aron, A. R. (2008). Progress in executive-function research: From tasks to functions to regions to networks. *Current Directions in Psychological Science, 17*, 124–129.

Ashburner, J., Ziviani, J., & Rodger, S. (2010). Surviving in the mainstream: Capacity of children with autism spectrum disorder to perform academically and regulate their emotions and behavior at school. *Research in Autism Spectrum Disorders, 4*(1), 18-27.

Baldessarini, R. J. (1997).Dopamine receptors and clinical medicine. In: K. A. Neve,& R. L. Neve (Eds.),*The dopamine receptors* (pp. 457-498). Totowa, NJ: Humana.

Banich, M. T. (2009). Executive function: The search for an integrated account. *Current Directions in Psychological Science*, *18*(2), 89-94.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121*, 65-94.

Barros, R. M., Silver, E. J., & Stein, R. E. K. (2009). School recess and group classroom behavior. *Pediatrics, 123*(2),431-436.

Barton, J., & Petty, J. (2010). What is the best dose of natural and green exercise for improving mental health? A multi-study analysis.*Environmental Science & Technology, 44,* 3947-3955.

Bell, M., & Fox, N. (1992). The relations between frontal brain electrical activity and cognitive development during infancy. *Child Development, 63,* 1142-1163.

Grant, D. A., & Berg, E. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in Weigl-type card-sorting problem. *Journal of*

Experimental Psychology, 38, 404–411.

Berlin, L., Bohlin, G., & Rydell, A.M. (2003). Relations between inhibition, executive functioning, and ADHD symptoms: A longitudinal study from age 5 to 8½ years. *Child Neuropsychology, 9*(4),255-266.

Berwid, O. G., & Halperin, J. M. (2012). Emerging support for a role of exercise in attention-deficit/hyperactivity disorder intervention planning. *Current Psychiatry Reports, 14*(5), 543-551.

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise.*Developmental Review, 30*(4), 331-551.

Best, J. R. (2012). Exergaming immediately enhances children's executive function. *Developmental Psychology, 48*(5), 1501-1510.

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive function after age 5: Changes and correlates. *Developmental Review, 29*(3), 180-200.

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences, 21*(4), 327-336.

Biederman, M. C., Monuteaux, A. E., Doyle, L. J., Seidman, T. E., Wilens, T. E., Ferrero, F., … Faraone, S. V. (2004). Impact of executive function deficits and attention-deficit/hyperactivity (ADHD) on academic outcomes in children. *Journal of Consulting and Clinical Psychology, 72*(5), 757-766.

Bierman, K. L., Nix, R. L., Greenberg, M. T., Blair, C., & Domitrovich, C. E. (2008). Executive functions and school readiness intervention: Impact, moderation, and mediation of the Head Start REDI program. *Developmental Psychopathology, 20*(3), 821-843.

Blakemore, S. J., & Choudhury, S. (2006). Development of the adolescent brain: Implications for executive function and social cognition.*Journal of Child Psychology and Psychiatry, 47*(3), 296-312.

Bogod, N. M., Mateer, C. A., & MacDonald, S. W. (2003). Self-awareness after traumatic brain injury: A comparison of measures and their relationship to executive functions. *Journal of the International Neuropsychological Society, 9*, 450–458

Budde, H., Voelcker-Rehage, C., Pietrabyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters, 441*, 219–223.

Bull, R., Johnston, R. S., & Roy, J. A. (1999). Exploring the roles of the visual-spatial sketch pad and central executive in children's arithmetical skills: Views from cognition and developmental neuropsychology. *Developmental Neuropsychology, 15*, 421–442.

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology, 19*(3), 273-293.

Burgess, P. W. (2000). Strategy application disorder: The role of thefrontal lobes in human multitasking. *Psychological Research, 63,*279–288.

Bush, G., Frazier, J. A., Rauch, S. L., Siedman, L. J., Whalen, P. J., Jenike, M. A., … Biederman, J. (1999). Anterior cingulate cortex dysfunction in attention-deficit/hyperactivity disorder revealed by fMRI and the Counting Stroop. *Biological Psychiatry, 45*, 1542–1552.

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96*(1), 31-42.

Capruso, D. X., &Levin, H. S. (2000). Neurobehavioral sequelae of head injury.In P. R. Cooper& J. G., Golfinos (Eds.), *Head Injury* (523-553). New York: McGraw-Hill.

Carlson S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology, 28*(2), 595–616.

Carter, C. S., Mintun, M., & Cohen, J. D. (1995). Interference andfacilitation effects during selective attention: an H215O PET studyof Stroop task performance. *Neuroimage, 2*, 264–72.

Castellanos, F. X., Sharp, W. S., Gottesman, R. F., Greenstein, D. K., Giedd, J. N., & Rapoport, J. L. (2003). Anatomic brain abnormalities in monozygotic twins discordant for attention deficit hyperactivity disorder. *American Journal of Psychiatry, 160*, 1693-1696.

Centers for Disease Control and Prevention (2014, August 25). *How much physical activity do you need?* Retrieved from http://www.cdc.gov/physicalactivity/everyone/guidelines/

Centers for Disease Control and Prevention (2014, September 20). *Facts About Physical Activity?* Retrieved from http://www.cdc.gov/physicalactivity/everyone/guidelines/

Chaddock, L., Hillman, C. H., Pontifex, M. B., Johnson, C. R., Raine, L. R., & Kramer, A. F. (2012). Childhood aerobic fitness predicts cognitive performance one year later. *Journal of Sports Sciences, 30*(5), 421-430.

Chang, Y. K., Liu, S., Yu, H. H., & Lee, Y. H. (2012). Effect of acute exercise on executive function in children with attention deficit hyperactivity disorder. *Archives of Clinical Neuropsychology*, *27*(2), 225-237.

Chaytor, N., Schmitter-Edgecombe, M., & Burr, R. (2006). Improving the ecological validity of executive functioning assessment. *Archives of Clinical Neuropsychology*, *21*(3), 217-227.

Chen, S. T., Sultzer, D. L., Hinkin, C. H., Mahler, M. E., & Cummings, J. L. (1998). Executive dysfunction in Alzheimer's disease: Association with neuropsychiatric symptoms and functional impairment. *Journal of Neuropsychiatry and Clinical Neurosciences*, *10*, 426–432.

Christ, S. E., Kanne, S. M., & Reiersen, A. M. (2010). Executive function in individuals with subthreshold autism traits. *Neuropsychology, 24*(5), 590-598.

Coe, D. P., Pivarnik, C. J., Womack, M. J., Reeves, R. M., & Malina, R. M. (2006). Effect of physical education and activity level on academic achievement in children. *Medicine & Science in Sports & Exercise*, *38*, 1515-1519.

Colcombe, S.,& Kramer, A. F. (2003).Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science*, *14*(2), 125–130.

Conners, C. K. (2002). Forty years of methylphenidate treatment in attentiondeficit hyperactivity disorder. *Journal of Attention Disorders*, *6*, 17–30.

Conners, C. K. (2008).*Conners' Rating Scales – Third Edition*. Toronto: Multi Health

Systems.

Cooley, E. L., & Morris, R. D. (1990). Attention in children: A neuropsychologically based model for assessment. *Developmental Neuropsychology, 6,* 239-274.

Council on School Health (2013).The crucial role of recess in school.*Pediatrics*, *131*(1), 183-188.

Cummings, J. L. (1993). Frontal-subcortical circuits and human behavior. *Archives of Neurology 50*, 873–880.

Davis, C. L., Tomporowski, P. D., Boyle, C. A., Waller, J. L., Miller, P. H., Naglieri, J. A., & Gregoski, M. (2007). Effects of aerobic exercise on overweight children's cognitive functioning: A randomized controlled trial. *Research Quarterly for Exercise and Sport*, *78*(5), 510-519.

Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., … Naglieri, J. A. (2011). Exercise improves executive function and achievement and alters brain activation in overweight children: A randomized, controlled trial. *Health Psychology*, *30*(1), 91-98.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*, 959-964.

Diamond, A., & Goldman-Rakic, P. S. (1989). Comparison of human infants and rhesus monkeys on Piaget's AB task: Evidence for dependence on dorsolateral prefrontal cortex. *Experimental Brain Research*, *74*(1), 24-40.

Diamond, A., & Taylor, C. (1998). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do". *Developmental Psychobiology, 29*(4), 315-334.

Diamantopoulou, S., Rydell, A. M., Thorell, L. B., Bohlin, G. (2007). Impact of executive functioning and symptoms of attention deficit hyperactivity disorder on children's peer relations and school performance. *Developmental Neuropsychology, 32*(1), 521-542.

Donnelly, J. E., & Lambourne, K. (2011). Classroom-based physical activity, cognition, and academic achievement. *Preventive Medicine, 52,* 36-42.

Duke, L. M., & Kaszniak, A.W. (2000). Executive functions in degenerative dementias: A comparative review. *Neuropsychology Review, 10,* 75–99.

Eling, P., Derckx, K., & Maes, R. (2008). On the historical and conceptual background of the Wisconsin Card Sorting Test. *Brain and Cognition, 67,* 247–253.

Ellemberg, D., & St. Louis-Deschênes, M. (2010). The effect of acute physical activity on cognitive function during development. *Psychology of Sport and Exercise, 11,* 122–126.

Espy, K. A. (1997). The shape school: Assessing executive function in preschool children. *Developmental Neuropsychology, 13,* 495–499.

Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology, 26*(1), 465–486.

Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*(3), 205-228.

Etnier, J. L., Nowell, P. M., Landers, D. M., &Sibley, B. A. (2006). A meta-regression to examine the relationship between aerobic fitness and cognitive performance. *Brain Research Review, 52*(1), 119–130.

Ettlinger, G., Teuber, H., and Milner, B. (1975). The seventeenth International Symposium of Neuropsychology.*Neuropsychologia, 13,* 125–133.

Fisher, A., Boyle, J. M. E., Paton, J. Y., Tomporowski, P., Watson, C., McColl, J. H., & Reilly, J. J. (2011). Effects of physical education intervention on cognitive function in young children: randomized controlled pilot study. *BMC Pediatrics, 11*, 97-106.

Flanagan, D. P., Ortiz, S. O., & Alfonso, V. C. (2013). *Essentials of cross-battery Assessment* (3rd ed.). New York: Wiley Press.

Flook, L., Smalley, S. L., & Kitil, M. J. (2010). Effects of mindful awareness practices on executive functions in elementary school children. *Journal of Applied School Psychology, 26,* 70-95.

Fuster, J. N. M. (2000). The prefrontal cortex of the primate: A synopsis. *Psychobiology, 28*, 125–131.

Gapin, J. I., & Etnier, J. L. (2010). The relationship between physical activity and executive function performance in children with attention deficit hyperactivity disorder. *Journal of Sports and Exercise in Psychology, 32,* 753-763.

Gapin, J. I., Labban, J. D., & Etnier, J. L. (2011). The effects of physical activity on attention deficit hyperactivity disorder symptoms: The evidence. *Preventative Medicine, 52,* 70-74.

Gathercole, S. E., & Pickering, S. J. (2000a). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology, 70*, 177–194.

Gathercole, S. E., & Pickering, S. J. (2000b). Assessment of working memory in six- and seven-year old children. *Journal of Educational Psychology, 92*, 377–390.

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from National Curriculum Assessments at 7 and 14 years of age.*Applied Cognitive Psychology, 18*(1), 1–16.

Gaub, M., & Carlson, C. L. (1997). Behavioral characteristics of DSM-IV ADHD subtypes in a school-based population. *Journal of Abnormal Child Psychology, 25*(2), 103-111.

Gioia, G., Isquith, P., & Guy, S. (2001). Assessment of executive functions in children with neurological impairment. In R. Simeonsson & S. Rosenthal (Eds.). *Psychological and developmental assessment: Children with disabilities and chronic conditions* (317-356). New York: The Guildford Press.

Goekint, M., Bos, I., Heyman, E., Meeusen, R., Michotte, Y., & Sarre, S. (2012). Acute running stimulates hippocampal dopaminergic transmission in rats, but has no influence on brain-derived neurotrophic factors. *Journal of Applied Physiology, 112*(4), 535-541.

Goldberg, E., & Seidman, L. J. (1991). Higher cortical functions in normals and in schizophrenia: A selective review. In H. A. Nasrallah (Eds.), Handbook of schizophrenia. Amsterdam: Elsevier.

Grafman, J., & Litvan, I. (1999). Recognizing the importance of deficits in executive functions. *Lancet, 354*, 1921–1923.

Green, M. (1996). What are the functional consequences of neurocognitive deficits in schizophrenia? *American Journal of Psychiatry, 153*, 321–

330.

Gregory, S. M., Parker, B., & Thompson, P. D. (2012). Physical activity, cognitive function, and brain health: What is the role of exercise training in the prevention of dementia? *Brain Science*, *2*, 684-708.

Greenhill, L. L., Halperin, J. M., Abikoff, H. (1999). Stimulant medications. *Journal of American Academy Child and Adolescent Psychiatry, 38,* 503-512.

Halperin, J. M., Matier, K., Bedi, G., Sharma, V., & Newcorn, J. H. (1992). Specificity of inattention, impulsivity, and hyperactivity to the diagnosis of attention-deficit hyperactivity disorder. *Journal of the American Academy of Child & Adolescent Psychiatry, 31*(2), 190-196.

Harlacher, J., Merrell, K., & Roberts, N. (2006). Classwide interventions for students with ADHD: A summary of teacher opinions beneficial for the whole class. *Councelling Exceptional Children, 39,* 6-12.

Hattori, S., Naoi, M., & Nishino, H. (1994). Striatal dopamine turnover during treadmill running in the rat: Relation to the speed of running. *Brain Research Bulletin*, *35*(1),41-49.

Helland, T., & Asbjørnsen, A. (2000). Executive functions in dyslexia. *Child Neuropsychology, 6*(1), 37–48.

Henry, L. A., Messer, D. J., Nash, G. (2012). Executive functioning in children with specific language impairment. *Journal of Child Psychology and Psychiatry*, *53*(1), 37-45.

Hill, E. L. (2004). Executive dysfunction in autism.*Trends in Cognitive Sciences, 8*, 26-32.

Hillman, C. H., Castelli, D. M., & Buck, S. M. (2005). Aerobic fitness and neurocognitive function in healthy preadolescent children. *Medicine and Science in Sports and Exercise, 37*(11), 1967-1974.

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *National Review of Neuroscience, 9,* 58-65.

Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience, 3*, 1044–1054.

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44,* 2017-2036.

Janssen, I., & LeBlanc, A. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7,* 40-56.

Jonides, J., Smith, E. E., Koeppe, R. A., Awh, E., Minoshima, S., & Mintun, M. A. (1993). Spatial working memory in humans as revealed by PET. *Nature, 363,* 623–625.

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context:Past, present, and future. *Clinical Psychology: Science and Practice, 10*(2), 144–156.

Karapetsas, A., & Vlachos, F. (1997). Sex and handedness in development of visuomotor skills. *Perceptual and Motor Skills, 85,* 131-140.

Kenworthy, L. E., Black, D. O., Wallace, G. L., Ahluvalia, T., Wagner, A. E., & Sirian, L. M. (2005). Disorganization: The forgotten executive dysfunction in high-functioning Autism (HFA) Spectrum Disorders. *Developmental Neuropsychology, 28*(3), 809-827.

Klimkeit, E. I., Mattingley, J. B., Sheppard, D. M., Farrow, M., & Bradshaw, J. L. (2004). Examining the development of attention and executive functions in children with a novel paradigm. *Child Neuropsychology, 10*(3), 201-211.

Krikorian, R. & Bartok, J. (1998). Developmental data for the Porteus Maze Test.*The Clinical Neuropsychologist, 12,* 305-310.

Kroesbergen, E. H., Van Luit, J. E., Van Lieshout, E. C.,Van Loosbroek, E., & Van de Rijt, B. A. (2009). Individual differences in early numeracy: The role of executive functions and subsidizing. *Journal of Psychoeducational Assessment, 27,* 226-236.

Lakes, K. D., & Hoyt, W. T. (2004). Promoting self-regulation through school-based martial arts training. *Applied Developmental Psychology, 25,* 283-302.

Lan, X., Legare, C. H., Ponitz, C. C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: A cross-cultural analysis of Chinese and American preschoolers. *Journal of Experimental Child Psychology, 108*(3), 677-692.

Leung, H. C., Skudlarski, P., Gatenby, J. C., Peterson, B. S., & Gore, J. C. (2000). An event-related functional MRI study of the Stroop Color Word Interference task. *Cerebral Cortex, 10*(6), 552-560.

Lezak, M. D. (1982). The problem of assessing executive functions.*International Journal of Psychology, 17,* 281–297.

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological Assessment* (5th eds.). New York: Oxford University Press.

Lipina, S., Martelli, M. I., Vuelta, B., & Colombo, J. A. (2005). Performance of the A-not-B task of Argentinean infants from unsatisfied and satisfied basic needs homes. *Interamerican Journal of Psychology, 39*(1), 49–60.

Luria, A. R. (1973). *The frontal lobes and the regulation of behavior: Psychophysiology of the frontal lobes*. Oxford, England: Academic Press.

Luria, A. R., Homskaya, E. D., Blinkov, S. M. (1967). Impaired selectivity of mental processes in association with a lesion of the frontal lobe. *Neuropsychologia*, *5*, 105–117.

Malloy, P. F., & Richardson, E. D. (2001).Assessment of frontal lobe functions. In S. P. Salloway, P. F. Malloy, & J. D. Duffy (Eds.). *The frontal lobes and neuropsychiatric illness* (125–137).Washington, DC: American Psychiatric Publishing.

Manly, T., Anderson, V., Nimmo-Smith, I., Turner, A., Watson, P., & Robertson, I. H. (2001). The differential assessment of children's attention: The Test of Everyday Attention for Children (TEA-Ch), normative sample and ADHD performance. *Journal of Child Psychology and Psychiatry, 42*(8), 1065-1081.

Manly, T. Robertson, I. H., Anderson, V., & Nimmo-Smith, I. (1999).*The Test of Everyday Attention for Children (TEA-Ch).*Bury St. Edmunds, England: Thames Valley Test Company.

Mathiesen, B. B., Farster, P. L. V., Svendsen, H. A. (2004). Affect regulation and loss of initiative in a case of orbitofrontal Injury. *Neuro-Psychoanal, 6,* 47–62.

Mattson, S. N., Goodman, A. M., Caine, C., Delis, D. C., & Riley, E. P. (1999). Executive functioning in children with heavy prenatal alcohol exposure.*Clinical* *and Experimental Research, 23*(11), 1808-1815.

Mayberry, E. (Producer). (2010, August 10). Kidzercize: Kids exercise video by kids for kids. Retrieved from http://www.youtube.com/watch?v=6lLJ_QqnTJc

McClelland, M. M., Cameron, C. E., Wanless, S., B., & Murray, A. (2007). Executive function, behavioral self-regulation, and social–emotional competence: Links to school readiness. In O. N. Saracho & B. Spodek (Eds.), *Contemporary perspectives in early childhood education: Social learning in early childhood education* (113–137). Charlotte, NC: Information Age Publishing.

McLean, J. F., & Hitch, G. J. (1999). Working memory impairments in children with specific arithmetic learning difficulties. *Journal of Experimental Child Psychology, 74*, 240–260.

Medina, J. A., Netto, T. L., Muszkat, M., Medina, A. C., Botter, D., Orbetelli, R., … Miranda, M. C. (2010). Exercise impact on sustained attention of ADHD children, methylphenidate effects. *ADHD Attention Deficit Hyperactivity Disorder, 2,* 49-58.

Merrell, C., & Tymms, P. B. (2001). Inattention, hyperactivity and impulsiveness: Their impact on academic achievement and progress. *British Journal of Educational Psychology, 71*(1), 43-56.

Milner, B. (1971). Interhemispheric differences in the localization ofpsychological processes in man. *British Medical Bulletin, 27*, 272–277.

Mirsky, A. F., Anthony, B. J., Duncan, C. C., Ahearn, M. B., & Kellam, S. G. (1991). Analysis of the elements of attention: A neuropsychological approach. *Neuropsychology Review, 2*(2), 109-145.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*(1), 8-14.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., & Howerter, A. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-100.

Molina, B. S., Hinshaw, S. P., Swanson, J. M., Arnold, L. E., Vitiello, B., Jensen, P. S., … Houck, P. R. (2009). The MTA at 8years: Prospective follow-up of children treated for combined-typeADHD in a multisite study. *Journal of American Academy of Child and Adolescent Psychiatry, 48*, 484–500.

Morgan, A. B., & Lilienfeld, S. O. (2000). A meta-analytic review of the relation between antisocial behavior and neuropsychological measures of executive function. *Clinical Psychology Review, 20*, 113–136.

Nair, J., Ehimare, U., Beitman, B. D., Nair, S. S., & Lavin, A. (2006). Clinical review: Evidence-based diagnosis and treatment of ADHD in children.*Missouri Medicine, 103*(6), 617-621.

NICHD Early Child Care Research Network (2003). Do children’s attention processes mediate the link between family predictors and school readiness? *Developmental Psychology, 39*(3), 581-593.

Nieuwenstein, M. R., Aleman, A., & de Haan, E. H. F. (2001). Relationship between symptom dimensions and neurocognitive functioning in schizophrenia: A meta-analysis of WCST and CPT studies. *Journal of Psychiatric Research, 35*. 119–125.

Ozonoff, S. (1997).Components of executive function in autism and other disorders. In: J. Russell (Ed.), *Autism as an executive disorder* (179-211). Oxford: Oxford University Press.

Ozonoff, S., & Jensen, J. (1999). Brief report: Specific executive function profiles in Three neurodevelopmental disorders. *Journal of Autism and Developmental Disorders, 29*(2), 171–177.

Ozonoff, S., & Strayer, D. L. (2001). Further evidence of intactworking memory in autism. *Journal of Autism and Developmental Disorders, 31*, 257-263.

Pascualvaca, D.M.,Fantie, B.D.,Papageorgiou,M.,& Mirsky, A.F.(1998). Attentional capacities in children with autism: Is there ageneral deficit in shifting focus? *Journal of Autism and Developmental Disorders, 28,* 467-478.

Passolunghi, M. C., & Siegel, L. S. (2001). Short-term memory, working memory, and inhibition control in children with difficulties in arithmetic problem solving. *Journal of Experimental Child Psychology, 80*(1), 44-57.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37,* 51–87.

Perry, W., Potterat, E. G., & Braff, D. L. (2001). Self-monitoring enhances Wisconsin Card Sorting Test performance in patients with schizophrenia: Performance is improved by simply asking patients to verbalize their sorting strategy. *Journal of the International Neuropsychological Society, 7,* 344–352.

Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity, 2*, 16–22.

Peyrin, L., Pequignot, J. M, Lacour, J. R., & Fourcade, J. (1987). Relationships between catecholamine or 3-methoxy 4-hydroxy phenylglycol changes and the mental performance under submaximal exercise in man. *Psychopharmacology, 93*(2), 188-192.

Polderman, T. J., Gosso, M. F., Posthuma, D., Van Beusterveldt, T. C., Heutink, P., Verhulst, F. C., & Boomsma, D. I. (2006). A longitudinal study on IQ, executive functioning, and attention problems during childhood and early adolescence. *Acta Neurologica Belgica, 106,* 191-207.

Pontifex, M. B., Raine, L. B., Johnson, C. R., Chaddock, L., Voss, M. W., Cohen, N. J., … Hillman, C. H. (2011). Cardiorespiratory fitness and the flexible modulation of cognitive control in preadolescent children. *Journal of Cognitive Neuroscience, 23*(6), 1332-1345.

Preston, A. S., Heaton, S. C., McCann, S. J., Watson, W. D., & Selke, G. (2009). The role of multidimensional attentional abilities in academic skills of children with ADHD. *Journal of Learning Disabilities, 42*(3), 240-249.

Querido, J. S., & Sheel, A. W. (2007). Regulation of cerebral blood flow during exercise, *Sports Medicine, 37*(9), 765-782.

Rabiner, D., & Coie, J. D. (2000). Early attention problems and children's reading achievement: A longitudinal investigation. *Journal of the American Academy of Child & Adolescent Psychiatry, 39*(7), 859-867.

Rebok, G. W., Smith, C. B., Pascualvaca, D. M., Mirsky, A. F., Anthony, B. J., & Kellam, S. G. (1997). Developmental changes in attentional performance in urban children from eight to thirteen years. *Child Neuropsychology, 3*(1), 28-46.

Reed, R. B. & Stuart, H. C. (1959). Patterns of growth in height and weight from birth to eighteen years of age. *Pediatrics, 24*(5), 904-921.

Riccio, C. A., Reynolds, C. R., Lowe, P., & Moore, J. J. (2002). The Continuous Performance Test: A window on the neural substrates for attention? *Archives of Clinical Neuropsychology, 17*(3), 235-272.

Riggs, N., Blair, C., & Greenberg, M. (2003). Concurrent and 2-year longitudinal relations between executive function and the behavior of 1st and 2nd grade children. *Child Neuropsychology, 9*, 267-276.

Rose, S. A., Feldman, J. F., &Jankowski, J. J. (2009). Information processing in toddlers: Continuity from infancy and persistence of preterm deficits.*Intelligence, 37,* 311-320.

Rosvold, H., Mirsky, A., Sarason, E., Bransome, E. D., & Beck, L. H. (1956). A continuous performance test of brain damage. *Journal of Consulting Psychology, 20,* 343-350.

Russell, J. (1997). *Autism as an executive disorder*.Oxford: Oxford University Press.

Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development

of executive functioning and theory of mind: A comparison of Chinese and U.S. preschoolers. *Psychological Science, 17*, 74–81.

Scahill, R. I., Frost, C., Jenkins, R., Whitwell, J. L., & Rossor, M. N. (2003). A longitudinal study of brain volume changes in normal aging using serial registered magnetic resonance imaging. *Archives of Neurology, 60*(7), 989-994.

Scarmeas, N., Stern, Y. (2003). Cognitive reserve and lifestyle.*Journal of Clinical and*

Experimental Neuropsychology, 25, 625-633.

Schmidt, R. A. (1988). Motor control and learning: A behavioral emphasis (2nd ed.). Champaign: Human Kinetics.

Semrud-Clikeman, M., Pliszka, S., & Liotti, M. (2008). Executive functioning in children with attention-deficit/hyperactivity disorder: Combined type with and without a stimulant medication history. *Neuropsychology, 22*(3), 329-340.

Sergeant, J. A., Geurts, H., & Oosterlaan, J. (2002). How specific is a deficit of executive functioning for attention-deficit/hyperactivity disorder? *Behavioural Brain Research, 130*(1-2), 3-28.

Sewards, T. V., Sewards, M. A. (2003). Representations of motivational drives in mesial cortex, medial thalamus, hypothalamus and midbrain. *Brain Research Bulletin, 61*, 25–49.

Shaw, P., Lerch, J., Grenstein, D., Sharp, D., Clasen, L., Evans, A., … Rapoport, J. (2006). Longitudinal mapping of cortical thicknessand clinical outcome in children and adolescentswith attention-deficit/hyperactivity disorder. *Archives of General Psychiatry, 63*, 540-549.

Shimamura, A. R. (2000). The role of the prefrontal cortex in dynamic filtering. *Psychobiology, 28*(2), 207-218.

Shu, B. C., Lung, F. W., Tien, A. Y., & Chen, B. C. (2001).Executive function deficits in non-retarded autistic children. *Autism, 5*, 165-174.

Sibley, B. A. & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta analysis. *Pediatric Exercise in Science, 15,* 243-256.

Smith, P. J., Blumenthal, J. A., Hoffman, B. M., Cooper, H., Strauman, T. A., Welsh-

Bohmer, K., … Sherwood, A. (2010). Aerobic exercise and neurocognitive performance: A meta-analytic review of randomized controlled trials. *Psychosomatic Medicine, 72,* 239-252.

Spencer, T., Biederman, J., Wilens, T., Harding, M., O'Donnell, D., & Griffin, S. (1996). Pharmacotherapy ofattention-deficit hyperactivity disorder across the life cycle. *Journal of the American Academy of Child Adolescent Psychiatry, 35,* 409–32.

Stevens, C. & Bavelier, D. (2012). The role of selective attention on academic foundations: A cognitive neuroscience perspective. *Developmental Cognitive Neuroscience, 2*(1), 30-48.

Stevens, C., Lauinger, B., & Neville, H. (2009). Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: An event-related brain potential study. *Developmental Science, 12*(4), 634-646.

Strauss, E., Sherman, E. M. S., & Spreen, O. (2006). *A compendium of neuropsychological tests: Administration, norms, and commentary (3rd ed.).* New York: Oxford University Press.

Strong, W. B., Malina, R. B., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., … Trudeau, F. (2005). Evidence based physical activity for school-age youth. *The Journal of Pediatrics, 146*(6), 732-737.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions.*Journal of Experimental Psychology, 18,* 643–662.

Stuss, D. T., Alexander, M. P., Floden, D., Binns, M. A., Levine, B., McIntosh, A. R., … Havenor, S. J. (2002).Fractionation and localization of distinct frontal lobe processes: Evidence from focal lesions in humans. In D. T. Stuss & R. T. Knight

(Eds.), Principles of frontal lobe function (392-407). London: Oxford University Press.

Stuss, D. T., Floden, D., Alexander, M. P., Levine, B., & Katz, D.(2001). Stroop performance in focal lesion patients: Dissociationof processes and frontal lobe lesion location. *Neuropsychologia, 39*, 771–786.

Stuss, D. T., Levine, B., Alexander, M. P., Hong, J., Palumbo, C., Hamer, L., … Isukawa, D. (2000). Wisconsin Card SortingTest performance in patients with focal frontal and posterior braindamage: Effects of lesion location and test structure on separable cognitive processes. *Neuropsychologia, 38*, 388–402.

Suchy, Y. (2009). Executive functioning: Overview, assessment, and research issues for non-neuropsychologists. *Annals of Behavioral Medicine, 37,* 106-116.

Swanson, H. L. (1999). Reading comprehension and working memory in learning-disabled readers: Is the phonological loop more important than the executive system? *Journal of Experimental Child Psychology, 72*, 1–31.

Thorell, L. B., Lindqvist, S., Nutley, S. B., Bohlin, G., & Klingberg, T. (2008). Training and transfer effects of executive functions in preschool children. *Developmental Science*, *12*(1), 106-113.

Thompson, P. D., Buchner, D., Pina, I. L., Balady, G. J., Williams, M. A., Marcus, B. H., … Wenger, N. K. (2003). Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease. *Circulation, 107,* 3109-3116.

Turner, M. A. (1999). Generating novel ideas: Fluency performancein high-functioning and learning disabled individualswith autism. *Journal of Child Psychology and Psychiatry, 40,*189-201.

Tremblay, L., & Schultz, W. (2000). Reward-related neuronal activityduring go-nogo task performance in primate orbitofrontal cortex.Journal of Neurophysiology, 83, 1864–1876.

Uhrich, T. A. & Swalm, R. L. (2007). A pilot study of a possible effect from a motor task on reading performance. *Perceptual and Motor Skills, 104,* 1035-1041.

Van ‘t Ent, D., Van Beijsterveldt, C. E., Derks, E. M., Hudziak, J. J., Veltman, D. J., Todd, R. D., … De Geus, E. J. (2009). Neuroimaging of response interefence in twins concordant or discordant for inattention and hyperactivity symptoms. *Neuroscience, 164*(1), 16-29.

Verte, S., Geurts, H. M., Roeyers, H., Ooserlaan, J., & Sergeant, J. A. (2006). Executive functioning in children with an Autism Spectrum Disorder: Can we differentiate within the spectrum? *Journal of Autism and Developmental Disorders, 36*(3), 351-372.

Vriezen, E. R., & Pigott, S. E. (2002). The relationship between parental report on the BRIEF and performance-based measures of executive function in children with moderate to severe traumatic brain injury. *Child Neuropsychology, 8*(4), 296-303.

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children – Fourth Edition*. San Antonio, TX: Psychological Cooperation.

Welsh, M. C. (2002). Developmental and clinical variations in executive functions.In D. L. Molfese, & V. J. Molfese (Eds.), *Developmentalvariations in learning: Applications to social, executive function, language,and reading skills* (139–185). Mahwah, NJ: Lawrence Erlbaum Associates.

Welsh, C. M., Pennington, B. F., Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children.

Developmental Neuropsychology, 7(2), 131-149.

Whalley, L. J., Deary, I. J., Appleton, C. L., & Starr, J. M. (2004). Cognitive reserve and the neurobiology of cognitive aging. *Ageing Research Reviews, 3,* 369-382.

Wilson, B. A. (1993). Ecological validity of neuropsychological assessment: Do neuropsychological indexes predict performance on everyday activities? *Applied and Preventative Psychology, 2,* 209-215.

Zelazo, P. D., & Muller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (445-469). Oxford: Blackwell.

Zickefoose, S., Hux, K., Brown, J., & Wulf, K. (2013). Let the games begin: A preliminary study using attention process training-3 and Lumosity™ brain games to remediate attention deficits following traumatic brain injury. *Brain Injury, 27*(6), 707-716.

Table 1

Demographic Statistics for Total Sample

	Exercise Condition		Control Condition	
	N	%	*N*	%
Sex				
Male	5	38.5	6	46.2
Female	8	61.5	7	53.8
Age				
10	3	23.1	3	23.1
11	3	23.1	1	7.7
12	2	15.4	2	15.4
13	5	38.5	7	53.9
Ethnicity				
Caucasian	10	76.9	9	69.2
African-Canadian	1	7.7	2	15.4
First Nations	0	0	1	7.7
Mixed Ethnicity	2	15.4	1	7.7

Table 2

Means and Standard Deviations for Group Characteristics by Experimental Condition

	Exercise Condition		Control Condition			
	M	*SD*	*M*	*SD*	*t*	*p*
WISC-IV						
Digit Span	9.9	2.8	9.5	2.2	.47	.64
Letter Number Sequencing	8.8	2.2	8.7	2.3	.18	.86
Perceived Exertion	6.3	1.2	2.0	1.0	10.03	.01

Table 3

Means and Standard Deviations for Attention Variables by Experimental Condition

	Exercise Condition		Control Condition	
	M	*SD*	*M*	*SD*
TEA-Ch				
Sky Search	10.9	2.9	10.4	2.3
Score!	11.0	2.5	8.6	3.9
Creature Counting	11.9	2.4	8.2	3.6
Sky Search Dual Task	8.5	1.5	6.6	2.3

Appendix A

Demographic and History Questionnaire

Demographic & History Questionnaire

Please fill out the following.We are asking these questions to learn about the individuals taking part in this study.

For reasons of confidentiality, please do not include your name anywhere on this questionnaire.

ID number: ________________________________ Date Form Filled Out: ____________

Gender: [ ] Male [ ] Female

Date of Birth: __ __ / __ __ / __ __ __ __
Day Month Year

Race: [ ] Native Canadian (e.g., First Nations, Metis)
[ ] Black / African Canadian
[ ] Caucasian / Euro Canadian
[ ] Asian Canadian
[ ] Hispanic Canadian
[ ] Other: ______________________________

<u>Family Composition</u>

1. What is your highest level of education? Check all that apply.
    - [ ] Less than High School (Highest grade completed: ______)
    - [ ] High School Diploma
    - [ ] Some Community College
    - [ ] Community College Diploma
    - [ ] Some University
    - [ ] University Degree
    - [ ] Graduate Degree (specify __________)

2. What is your occupation? Check all that apply.
   Occupation: ______________________
    - [ ] I work outside the home:
    - [ ] Part-time
    - [ ] Full-time
    - [ ] Stay at home parent
    - [ ] Student
    - [ ] Unemployed

Medical History

3. Please check all diagnoses that currently apply to you.
   [ ] Autistic Disorder
   [ ] Asperger's Disorder
   [ ] Attention Deficit-Hyperactivity Disorder
   [ ] Tourette Syndrome or tics
   [ ] Oppositional Defiant Disorder
   [ ] Conduct Disorder
   [ ] Anxiety (specify type ________________________________)
   [ ] Depression
   [ ] Learning Disability (specific type/difficulty _______________________)
   [ ] Other (please specify): __________________________________
   [ ] I do not have any diagnosis

4. Who provided the diagnosis? (if more than one diagnosis apply, please indicate who made each one and what year each one was made)
   [ ] Family Doctor
   [ ] Pediatrician
   [ ] Psychologist
   [ ] Psychiatrist
   [ ] Other (please specify): __________________________________
   When was the diagnosis made?

____

5. Are you presently taking any prescribed medication?
   [ ] Yes (If yes, please answer questions 6 to 8)
   [ ] No

6. What do you take this medication for? Check all that apply.
   [ ] Epilepsy
   [ ] Hyperactivity
   [ ] Attention/Concentration Problems
   [ ] Behavioural Problems
   [ ] Anxiety
   [ ] Depression
   [ ] Infection
   [ ] Asthma
   [ ] Other (please specify): ___________________________

7. What prescribed medication do you take? Check all that apply.
   [ ] Antibiotics
   [ ] Ritalin/Concerta
   [ ] Dexedrine
   [ ] Strattera

[ ] Tranquilizers or nerve pills
[ ] Anti-convulsants or anti-epileptic pills
[ ] Anti-Depressant
[ ] Anti-Anxiety
[ ] Asthma medication
[ ] Other (please specify): ______________________________

8. What is the present dosage of medication? ____________________

Family History

9. Do you have a family history of any of the following? If yes, please indicate which family member(s) according to their relationship to you, i.e., your maternal aunt, your paternal cousin. Do not include the name of or any other information about the family member.

[ ] Autistic Disorder
Family Member: ________________________
[ ] Asperger's Disorder
Family Member: ________________________
[ ] Attention Deficit-Hyperactivity Disorder
Family Member: ________________________
[ ] Anxiety (specify type __________________________________)
Family Member: ________________________
[ ] Obsessive-Compulsive Disorder
Family Member: ________________________
[ ] Tourette Syndrome or tics
Family Member: ________________________
[ ] Bipolar Disorder or Manic-Depression
Family Member: ________________________
[ ] Depression
Family Member: ________________________
[ ] Schizophrenia
Family Member: ________________________
[ ] Learning Disability (specific type/difficulty ________________________)
Family Member: ________________________
[ ] Other (please specify): ____________________________________
Family Member: ________________________

Appendix B

The Physical Activity Readiness Questionnaire for Everyone

CSEP approved Sept 12 2011 version: for use by CSEP Certified Exercise Physiologists®

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH

	Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1.	Has your doctor ever said that you have a heart condition OR high blood pressure?	☐	☐
2.	Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	☐	☐
3.	Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4.	Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	☐	☐
5.	Are you currently taking prescribed medications for a chronic medical condition?	☐	☐
6.	Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.	☐	☐
7.	Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.

Go to Section 3 to sign the form. You do not need to complete Section 2.

› Start becoming much more physically active – start slowly and build up gradually.
› Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
› You may take part in a health and fitness appraisal.
› If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist® (CSEP-CEP).
› If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the questions above, please GO TO SECTION 2.

Delay becoming more active if:
› You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
› You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
› Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

CSEP | SCPE THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

SECTION 2 - CHRONIC MEDICAL CONDITIONS

Please read the questions below carefully and answer each one honestly: check YES or NO.			YES	NO
1.	Do you have Arthritis, Osteoporosis, or Back Problems?		☐ If yes, answer questions 1a-1c	☐ If no, go to question 2
	1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/ or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	☐	☐
	1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	☐	☐
2.	Do you have Cancer of any kind?		☐ If yes, answer questions 2a-2b	☐ If no, go to question 3
	2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	☐	☐
	2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	☐	☐
3.	Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm		☐ If yes, answer questions 3a-3e	☐ If no, go to question 4
	3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	3b.	Do you have an irregular heart beat that requires medical management? (e.g. atrial brillation, premature ventricular contraction)	☐	☐
	3c.	Do you have chronic heart failure?	☐	☐
	3d.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)	☐	☐
	3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	☐	☐
4.	Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes		☐ If yes, answer questions 4a-4c	☐ If no, go to question 5
	4a.	Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)	☐	☐
	4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?	☐	☐
	4c.	Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?	☐	☐
5.	Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)		☐ If yes, answer questions 5a-5b	☐ If no, go to question 6
	5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	5b.	Do you also have back problems affecting nerves or muscles?	☐	☐

CSEP | SCPE THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

CSEP approved Sept 12 2011 version

		Please read the questions below carefully and answer each one honestly: check YES or NO.	YES	NO
6.		Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure	☐ If yes, answer questions 6a-6d	☐ If no, go to question 7
	6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	6b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	☐	☐
	6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	☐	☐
	6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	☐	☐
7.		Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia	☐ If yes, answer questions 7a-7c	☐ If no, go to question 8
	7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	☐	☐
	7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	☐	☐
8.		Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event	☐ If yes, answer questions 8a-c	☐ If no, go to question 9
	8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	☐	☐
	8b.	Do you have any impairment in walking or mobility?	☐	☐
	8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	☐	☐
9.		Do you have any other medical condition not listed above or do you live with two chronic conditions?	☐ If yes, answer questions 9a-c	☐ If no, read the advice on page 4
	9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?	☐	☐
	9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	☐	☐
	9c.	Do you currently live with two chronic conditions?	☐	☐

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.

CSEP | SCPE
THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

CSEP approved Sept 12 2011 version

PAR-Q+

If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

- It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP) to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
- If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.

If you answered YES to one or more of the follow-up questions about your medical condition:

- You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal.

Delay becoming more active if:

- You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise profesional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 - DECLARATION

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.
- Please read and sign the declaration below:

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca

KEY REFERENCES

1. Jamnik VJ, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the eectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.

CSEP | SCPE THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

CSEP approved Sept 12 2011 version

Appendix C

Questionnaire of Perceived Exertion

Based on the exercise experience you just had, please rate your level of perceived exertion by circling a number below. *Note*: when rating your perception of exertion, please consider your overall fatigue, fatigue or strain in your muscles, and feelings of breathlessness or aches/pains in your body.

1 --------- VERY VERY LIGHT (E.G., MINIMAL EXERTION)

2 --------- VERY LIGHT

3 --------- LIGHT

4 --------- SOMEWHAT LIGHT

5 --------- MODERATELY LIGHT

6 --------- MODERATELY HARD

7 --------- SOMEWHAT HARD

8 --------- HARD

9 --------- VERY HARD

10 --------- VERY VERY HARD (E.G., MAXIMUM EXERTION)