Article

Journal of Attention Disorders
16(1) 71–80

DOI: 10.1177/1087054710379735
http://jad.sagepub.com
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# A Physical Activity Program Improves Behavior and Cognitive Functions in Children With ADHD: An Exploratory Study

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## Abstract

**Objective:** The objective of this study is to explore the effects of a moderate- to high-intensity physical activity program on fitness, cognitive functions, and ADHD-related behavior in children with ADHD. **Method:** Fitness level, motor skills, behaviors, and cognitive functions are assessed by standardized tests before and after a 10-week training or control period. **Results:** Findings show that participation in a physical activity program improves muscular capacities, motor skills, behavior reports by parents and teachers, and level of information processing. **Conclusion:** A structured physical activity program may have clinical relevance in the functional adaptation of children with ADHD. This supports the need for further research in the area of physical activity with this population. *(J. of Att. Dis. 2012; 16(1) 71-80)*

## Keywords

attention-deficit hyperactivity disorder, exercise,cognition, attention

The inattention and hyperactivity-impulsivity that characterize children with attention-deficit hyperactivity disorder (ADHD) are associated with organisational problems, risk for achievement difficulties, and extensive negative criticism from parents and teachers (Landau, Milich, & Diener, 1998). These children experience negative outcomes in personal, educational, and social domains that might impair their functional adaptation throughout their life (Barkley, Fischer, Smallish, & Fletcher, 2006). Central nervous system stimulants and behavioral interventions, including parents' training, classroom, and peer interventions, are considered effective treatments for ADHD (Pelham & Fabiano, 2008; Pelham et al., 2000). A growing body of literature has suggested that sport and exercise could be of benefit for a number of cognition-related variables (Hillman, Erickson, & Kramer, 2008). Conclusions of several experiments conducted with animals as well as in adult humans suggest that physical activity performed on a regular basis can alter brain functions underlying cognition and behavior (Tomporowski, Davis, Miller, & Naglieri, 2008). The mechanisms are not yet fully elucidated (Buck, Hillman, & Castelli, 2007). Some researchers argue that voluntary physical activity can positively alter brain plasticity by neurogenerative, neuroadaptative, and neuroprotective processes (Dishman et al., 2006). Other researchers also add that the potential changes in cognition may be linked to psychological mechanisms such as self-esteem or attitudes following a physical activity program (Etnier et al., 1997). The effect of physical activity on specific domains of child development such as cognitive function has received little attention to date (Hillman et al., 2008). This is especially true for children with mental health conditions such as ADHD.

In the general population of children, academic performance is one of the most studied variables in this area of research. Correlational studies provide evidence, suggesting a positive association between results from aerobic fitness tests (Castelli, Hillman, Buck, & Erwin, 2007; Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001) or amount of moderate-to-vigorous physical activity (Coe, Pivarnik, Womack, Reeves,

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& Malina, 2006) and academic performance. However, there are other reports as well that found equivocal results (Ahamed et al., 2007; Lindner, 2002) or a negative relationship (Lindner, 2002; Tremblay, Inman, & Willms, 2000). Results from longitudinal studies are difficult to interpret due to methodological inconsistencies. The few studies available do, however, suggest that time spent in physical activity programs does not have a negative impact on children's academic performance (Tomporowski et al., 2008).

A meta-analysis, looking at other cognitive variables, was published in 2003 (Sibley & Etnier). According to the authors, various cognition assessments such as perceptual skills, developmental level, academic readiness, intellectual quotient, academic achievement, and results on math verbal tests have been positively related to physical activity in a general population of school-aged children. However, they did not find any effect on memory assessments. Recently, the impacts of exercise on children's cognitive process have been assessed in cross-sectional studies. Buck, Hillman, and Castelli (2007) found that a higher level of aerobic fitness was associated with better interference control, a component of the executive control, in a task performance (Stroop Task) in children without disabilities. These authors had already shown that a high level of fitness was associated with parameters of attention, working memory, and speed response in children (Hillman, Castelli, & Buck, 2005). They suggest that their findings add support to the beneficial effects of physical activity, or fitness level, on cognitive performance during development in preadolescent children (Buck et al., 2007). Moreover, a recent review of several large-scale experimental studies suggests that physical activity training exerts specific effects on cognitive functions of children from the general population (Tomporowski et al., 2008). Indeed, children participating in aerobic physical activity training in those studies improved on tests involving executive functions such as planning but not on other cognitive variables such as attention, simultaneous or successive functioning, perceptual skills, and visuomotor coordination.

Those results are especially interesting for children with ADHD in light of the ADHD theoretical model of Barkley (1997) that suggests that inhibition is the principal deficit of this disorder. This inhibition deficit impedes four executive neuropsychological functions: working memory, self-regulation of affect, internalization of speech, and reconstitution leading to problems of behavioral self-regulation (inattention, hyperactivity-impulsivity). Therefore, if physical activity can improve inhibition and executive functions, one could expect an improvement of self-regulation. However, conclusions on the impact of physical activity on behavior or cognitive functions are few and divergent for children in populations with mental health conditions (Tomporowski, 2003). Furthermore, methodological issues such as lack of statistical power and heterogeneity of the clinical population studied have been reported in the literature (Sibley & Etnier, 2003; Tomporowski, 2003). Moreover, few researchers have considered only children with ADHD in their studies (Tomporowski, 2003).

The few available longitudinal studies have reported divergent results on behavioral variables. In his unpublished thesis, Wendt (2000) observed significant improvements in behavior, as measured by the Conners Behavioral Rating Scale, in 13 children with ADHD after a 6-week physical activity program with a frequency of 5 sessions per week. Parish-Plass and Lufi (1998) used a combination of physical activity and social skills training during a 20-week program. They compared a sample of 43 boys with various disruptive behavior disorders, including 15 children with ADHD, with a control group. They observed a significant improvement in the number of behavioral deviant signs after the program. They concluded that these results provide initial support for the therapeutic value of a combination of physical activity and social skills training in children with behavioral disorders. Bluechard and Shepard (1995) reported different results. They assessed motor proficiency, teacher rating of social skills, and self-perception of personal competence in a sample of 45 children with learning disabilities randomly assigned to a trained group and a control group. After 10 weeks of a physical activity program combined with social skills activities, differences between groups were not apparent.

Acute effects of exercise have been associated with reductions in negative behaviors and improvements in acceptable behaviors and cognitive functions in children with clinical disorders categorized by poor impulse control and attention (Tomporowski, 2003). Nevertheless, conclusions are conflicting when looking specifically at children with ADHD. Few article have been published, and many are case studies looking for an impact of a physical activity program on behavioral and academic performances variables in children with ADHD. Etscheidt and Ayllon (1987) used 5-min exercise sessions to reduce hyperactive behaviors of a 13-year-old child with ADHD when he was not able to do his class work. The treatment produced a reduction in the percentage of negative behaviors during reading and arithmetic classes. Vigorous playground exercise has also produced positive results on attention behaviors when used as a reinforcement to promote calmness for a 4-year-old child with ADHD and autism (Azrin, Ehle, & Beaumont, 2006). Molloy (1989) assessed problem-solving performance in a sample of 32 children, including 2 children with ADHD. They reported that 5 min of cycling exercise was associated with improvement in the on-task attention behaviors of children with ADHD, compared to 10 min of exercise or no exercise. There was no effect on arithmetic performance. In 1983, in a study using 31 children with

ADHD, Craft failed to find any difference in cognitive performance, as assessed by an intelligence test (WISC-R), a digit span test, a coding test (WISC-R coding B), and a test of visual sequential memory (Illinois test of Psycholinguistic Abilities [ITPA]), after cycling bouts of 0, 1, 5, and 10 min adjusted for individual work capacities. More recently, using a sample of 19 boys with ADHD, Flohr, Saunders, Evans, and Raggi (2004) tried to determine whether low- or moderate-intensity cycling bouts of exercise influenced academic performance and class behavior assessed by an observation system. They found that children with ADHD had significantly improved behaviors following the two exercises periods. They did not find any difference for the academic performance. According to those studies, acute physical activity could improve some ADHD-related variables such as attention and negative behaviors.

The growing body of evidence supporting the beneficial effects of physical activity in the improvement of cognitive functions for different populations (Hillman et al., 2008) includes positive impacts on executive functions impaired in the ADHD (Hillman et al., 2005; Buck et al., 2007). Nevertheless, the diversity of the variables assessed as well as methodological issues in previous studies including children with ADHD do not allow for consensus.

## Objectives

Considering the clinical importance of an improvement in cognitive functions and behavior on the functional adaptation of children with ADHD, the objectives of this study were to assess the effects of a moderate- to high-intensity physical activity program lasting 10 weeks on fitness, cognitive functions, and behavior in children with ADHD. It was hypothesized that the program would result in improved fitness, ADHD-related behaviors, and cognitive functions such as attention and response inhibition.

## Method

### Participants

A total of 21 participants (age in years: $M = 9.1$, $SD = 1.1$, ranging from 7 to 12) took part in the study. They were recruited from a specialized ADHD clinic of the Rivière-des-Prairies Hospital and from a local school. Children who presented an ADHD inattentive subtype were not considered in this study because they are not included in the theoretical model of ADHD (Barkley, 1997). Children with learning disorders, autism, Tourette's syndrome, intellectual disabilities, epileptic disorders, or who took medication other than the usual ADHD stimulant treatment (methylphenidate) were also excluded from the study. The project was approved by the research ethics committee of the Rivière-des-Prairies Hospital. Informed consent was signed by parents.

### Diagnosis

All the participants had previously received an ADHD diagnosis according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.) criteria (American Psychiatric Association, 2000) by their pediatrician. They were evaluated individually in neuropsychology and psychiatry, in order to validate the preliminary diagnosis and to specify the differential diagnosis. After evaluations, two groups were formed: A group of 10 children with ADHD were assigned to the physical activity program, and a second group of 11 children with ADHD diagnoses were assigned to the control group. Due to recruitment difficulties, participants in the experimental group were recruited in the same school, whereas the control-group children were recruited from different areas. Both groups included only one girl. The children had the combined or the hyperactive-impulsive ADHD subtypes. Children with ADHD in the control group were all taking stimulant medication compared to 30% in the trained group. Parents and teachers were asked not to change medication regimen and behavioral management during the program.

### Physical Activity Training Program Monitoring

The training program took place during 10 consecutive weeks in a school gymnasium. It was held 3 times a week for 45-min periods at lunch time. All sessions were supervised by a physical activity specialist. Sessions included warm-up; progressive aerobic, muscular, and motor skills exercises; and cool down. The main objective was to maintain moderate to vigorous intensity in each session. Intensity was monitored by a heart-rate (HR) monitor (Polar S-810) once a week for each child. Various physical activities were used in order to maintain the motivation of the participants and the adherence in the program. Basketball, soccer, exercise stations, and tag and ball games were examples of aerobic activities used in the training sessions.

### Fitness and Motor Tests Measures

Fitness and motor performance tests were carried out within 10 days before the training program. The posttests were done within 1 week. The participants were informed not to practice intense physical activity and to cease any stimulant medication on the day preceding the evaluations. The tests were anthropometric measures and musculoskeletal aptitudes (Canadian Society for Exercise Physiology [CSEP], 1997), the Test of Gross Motor Development-2 (TGMD-2, Ulrich, 2000), as well as the Bruce treadmill protocol. Height, weight, body mass index (BMI), flexibility, muscular endurance, and resting and maximal HR were measured. Height and weight norms were provided by the CSEP (Docherty, 1996). The most recent growth norms provided by the U.S.

National Center for Health Statistics and the National Center for Disease Control and Prevention (2000) were used to transform BMI raw scores to percentiles. Flexibility was measured with the sit and reach test. Data on muscular endurance were obtained using the push-up (maximum number) and sit-up (maximum in 60 s) tests. Each test was validated in the Canadian population and norms are provided from the Canada Fitness Survey (Fitness Canada, 1985). Aerobic capacity was measured using the Bruce maximal progressive treadmill test. Percentiles were obtained by comparing running time with norms (Wessel, Strasburger, & Mitchell, 2001). During the aerobic test, HR was measured by a HR monitor (Polar S-810). Heart-rate data were recorded in the last 30 s of each test level, at minutes 1, 2, 5 at rest and during recovery, and at the maximum level reached by each participant.

Gross motor skills were assessed using the TGMD-2 (Ulrich, 2000). This test is subdivided in two parts and evaluates locomotor and object-control skills. The 12 tasks were run, gallop, hop, leap, horizontal jump, skip, and slide for the locomotor skills, as well as two-hand strike, stationary bounce, catch, kick, overhand throw, and underhand roll for object control. The TGMD-2 has good psychometric properties (Burton & Miller, 1998). It is considered in research settings as a reliable and valid fundamental movement skill assessment instrument (Harvey et al., 2007). The participants performed the test as described in the TGMD-2 examiner's manual. A score of 1 indicated that the participant performed a component correctly. Maximal scores for both locomotion and object control were 48. In the present study, instead of converting standardized scores per age group, the raw scores were used for the analyses, because children 11 and 12 years of age were included, which is outside the range of TGMD-2 normative data. The raw score for the locomotion and object-control skills as well as the sum of motor tests are reported.

### Behavioral Measures

Parents and teachers completed the Child Behavior Checklist (CBCL; Achenbach, 1991) before and after the physical activity program. This questionnaire evaluates behavioral problems and social competences of the children. This test has a good reliability coefficient ($r$ = .85) and has been used extensively in clinical and research settings. Eight scales were calculated: anxiety-depression (13 components), withdrawn-depression (8 components), somatic complaints (11 components), social problems (11 components), thought problems (15 components), attention problems (10 components), rule-breaking behaviors (17 components), and aggressive behaviors (18 components). Their compilation allows scaled computation of internalized, externalized, and total problems. Percentile scores calculated from the test manual are reported.

### Neuropsychological Measures

Attention functions and response inhibition were measured by the Test of Everyday Attention for Children (Tea-Ch; Manly, Robertson, Anderson, & Nimmo-Smith, 1999). The objectives of this test are to assess the different attentional capacities in children and adolescents from 6 to 16 years old. In this study, visual research skills were measured using the sky search part of the test, where participants have to detect similar targets among many presented, as quickly as possible. Auditory sustained attention was obtained using the *score* test part. In this task, the participants have to count the number of sounds heard. The Sky Search DT (Tea-Ch) was used to measure divided attention. This task requires the subject to perform the visual research task (sky search) and the auditory sustained attention task (*score*) simultaneously. The *walk/don't walk* part of the test was used to evaluate response inhibition. In this task, participants have to respond to a specific auditory signal but have to stop the response if the signal is followed by a different sound. The range of test–retest correlation coefficients between subtests is from $r$ = .70 (*walk/don't walk* ) to $r$ = .81 (*Sky Search DT*). Pondered scores adjusted for age are reported.

### Statistical Analysis

Group equivalence was tested using independent samples $t$ tests to check the usefulness of controlling for initial differences. Pretest levels of all variables were similar except for the withdrawn–depression scale of teacher's behavior questionnaires where the control group had a higher score (data not shown). However, the score was not in the range that is considered as a clinical problem. In order to assess the effects of the program, analysis of covariance was used to make comparisons, between trained and control groups, on posttest scores adjusted for differences in pretest scores. ANCOVA assumptions were established using visual inspection and "pretest X group" interaction test, the Shapiro–Wilk procedure for normality of sampling distribution on variable residuals, and Levene's test for homogeneity of variance. Because they provide higher statistical power, one-tailed tests were used based on a priori hypothesis for each of the two groups. Significance level was set at $p < .05$. Analyses were run using SPSS 10.0. There were missing data for some fitness and behavior measures; numbers of correct data are shown in the tables.

## Results

### Physical Activity Program

Heart rate and exercise duration were measured in order to monitor physical activity level. Average training duration per session was 47 min, and mean HR was 154 beats per

**Table 1.** Analysis of Covariance of Anthropometrical and Fitness Variables

| | Groups | | | | | | |
|---|---|---|---|---|---|---|---|
| | Physical activity group ($n$ = 10) | | Control group ($n$ = 8) | | | | |
| Variables | Posttest adjusted means | *SD* | Posttest adjusted means | *SD* | Pretest grand mean | $F(1, 18)$ | $p^a$ |
| Weight (kg) | 33.2 | 1.3 | 34.6 | 1.4 | 33.9 | 0.557 | .233 |
| Height (cm) | 139.0 | 0.3 | 140.7 | 0.4 | 138.1 | 11.808 | .002 |
| Body mass index (BMI) | 17.5 | 0.6 | 17.3 | 0.6 | 17.9 | 0.033 | .429 |
| Percentiles BMI | 56.5 | 8.7 | 54.8 | 9.8 | 60.6 | 0.015 | .452 |
| Push-up (max. number) | 17.8 | 2.1 | 12.1 | 2.5 | 12.5 | 3.187 | .048 |
| Sit-up (#/60 s) | 42.7 | 3.3 | 36.9 | 3.8 | 37.3 | 1.233 | .142 |
| Flexibility (cm) | 24.4 | 0.6 | 24.8 | 0.8 | 22.2 | 0.135 | .359 |
| Resting heart rate (b/min) | 83.8 | 2.7 | 78.7 | 3.1 | 90.6 | 1.456 | .124 |
| Bruce running time (min) | 10.6 | 0.6 | 11.3 | 0.7 | 11.0 | 0.618 | .222 |
| Bruce Percentiles | 61.2 | 11.4 | 54.2 | 13.6 | 63.8 | 0.153 | .350 |

[a]Refers to the unicaudal test.

minute (77% HR max). This that indicates an intensity in the moderate-to-vigorous category.

## Fitness

Baseline levels were in the normal range for all fitness parameters, compared to norms for the same age group. ANCOVA results showed that after the physical activity program, the only variable where a difference was observed was muscular capacity as assessed by the number of push-ups. Children from the physical activity group executed more push-ups than those from the control group (Table 1).

## Motor Performance

ANCOVA results for motor skills show a group difference for two variables: the locomotion score, $F(1, 14) = 8.885$; $p = .006$ (unicaudal test), and the total raw-motor-skills score, $F(1, 14) = 8.276$, $p = .007$ (unicaudal test). There was also a tendency for a higher object-control score, $F(1, 14) = 1.914$, $p = .087$ (unicaudal test). Figure 1 illustrates improvements on locomotion and total motor skills scores.

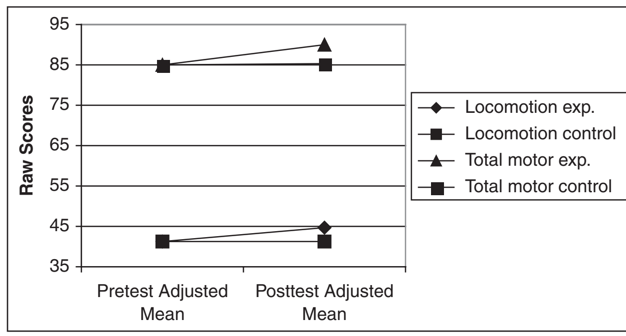


**Figure 1.** Analysis of covariance for locomotion skills and total motor skills raw scores

## Behavior

The impact of the physical activity program on behavior was assessed using parent and teacher forms of the CBCL. Posttest significant differences were observed for total problems score and for three subscales: social problems, thought problems, and attention problems (Table 2). There was also a tendency for the withdrawn–depression score. Each scale is composed of several specific components related to the principal definition of the scale. Paired $t$ tests on each component allowed the identification of which component was improved. There was a decrease of raw scores, though not reaching statistical significance, for the dependent behaviors and clumsy components of the social problems scale. Paired $t$ tests on separate components of the attention scale showed a significant decrease for the impulsive, $t(8)= 2.530$, $p = .035$, and a tendency for the inattentive component, $t(8)= 2.0$, $p = .081$ (data not shown).

Posttest analysis revealed that with the exception of rule-breaking behaviors, a tendency for improvements was reported by the teachers in the experimental group for all scales, but all differences did not reach statistical significance. ANCOVA results showed that children in the experimental group had a significantly lower anxiety-depression score, $F(1, 13) = 7.375$, $p = .01$, and fewer social problems, $F(1, 13) = 3.125$, $p = .05$. Specifically, paired $t$ tests showed a tendency for a significant reduction in the worthless component, $t(6) = 2.121$, $p = .078$, and the fearful component, $t(6) = 2.121$, $p = .078$, of the anxiety–depression scale (data not shown).

## Neuropsychological Measures

Significant posttest differences were observed for two neuropsychological variables. Children in the experimental group showed a higher level of information processing. They were

**Table 2.** Analysis of Covariance of Behavioral Variables Reported by Parents

| | Groups | | | | | | |
|---|---|---|---|---|---|---|---|
| | Physical activity group ($n$ = 9) | | Control group ($n$ = 9) | | | | |
| Variables | Posttest adjusted means | *SD* | Posttest adjusted means | *SD* | Pretest grand mean | $F(1, 16)$ | $p^a$ |
| Anxiety-depression | 71.4 | 21.6 | 82.8 | 17.5 | 84.2 | 0.550 | .235 |
| Withdrawn-depression | 79.9 | 3.1 | 87.2 | 3.1 | 81.8 | 2.765 | .059 |
| Somatic complaints | 66.1 | 6.0 | 72.1 | 6.0 | 72.9 | 0.509 | .243 |
| Social problems | 74.2 | 3.5 | 84.1 | 3.5 | 83.8 | 3.943 | .033 |
| Thought problems | 67.8 | 5.5 | 85.9 | 5.5 | 81.8 | 5.154 | .019 |
| Attention problems | 83.3 | 3.4 | 96.0 | 3.4 | 92.6 | 6.938 | .01 |
| Rule-breaking behaviors | 79.2 | 4.2 | 81.2 | 4.2 | 85.1 | 0.106 | .374 |
| Aggressive behaviors | 82.9 | 4.6 | 89.4 | 4.6 | 90.9 | 0.955 | .172 |
| Internalized problems | 75.9 | 6.5 | 76.0 | 6.9 | 84.6 | 0.000 | .497 |
| Externalized problems | 83.7 | 5.1 | 87.2 | 5.5 | 89.7 | 0.220 | .323 |
| Total problems | 78.8 | 4.4 | 91.3 | 4.7 | 90.8 | 3.681 | .038 |

[a] Refers to the unicaudal test.

**Table 3.** Analysis of Covariance of Neuropsychological Variables

| | Groups | | | | | | |
|---|---|---|---|---|---|---|---|
| | Physical activity group ($n$ = 10) | | Control group ($n$ = 11) | | | | |
| Variables | Posttest adjusted means | *SD* | Posttest adjusted means | *SD* | Pretest grand mean | $F(1, 19)$ | $p^a$ |
| Sky Search | | | | | | | |
| Time target pondered | 10.3 | 0.6 | 8.8 | 0.5 | 8.1 | 2.983 | .05 |
| Attention pondered | 10.0 | 0.6 | 9.6 | 0.6 | 7.9 | 0.221 | .322 |
| Score pondered | 7.8 | 0.8 | 5.4 | 0.8 | 7.9 | 3.847 | .03 |
| Sky Search DT pondered | 6.6 | 1.0 | 6.9 | 1.1 | 6.8 | 0.021 | .444 |
| Walk/don't walk pondered | 6.9 | 1.0 | 7.0 | 0.9 | 5.5 | 0.000 | .493 |

[a] Refers to the unicaudal test.

faster in the visual research as assessed by the time-target-pondered score of the Sky Search test (Table 3). They also had a higher outcome for the pondered *score* result that indicates a better auditory, sustained attention.

## Discussion

The objectives of this study were to assess the effects of a moderate-to-vigorous-intensity physical activity program on fitness, behavior, and cognitive functions in children with ADHD. To our knowledge, this is the first study exploring the effect of a physical activity program on those parameters in a sample of children with ADHD. The results show that the physical activity program had a positive impact. Motor performance was better in the experimental group as shown by the increase in locomotion and total motor skill scores. Moreover, positive, significant behavioral scores are reported by parents for total problems, social problems, thought problems, and attention problems, and from teachers, for anxiety-depression and social problems in the physical activity group. The level of information processing as assessed by visual research and auditory sustained attention tasks was also better for the experimental group. Baseline fitness parameters were similar, within the normal range in both groups, and did not differ after the physical activity program. The only exception was a higher number of push-ups in the experimental group after the program.

The higher scores of arm muscular strength, as assessed by the push-ups test, and of motor skills, were expected because the program included exercises targeting those variables. Specifically, motor skills exercises were included in the activities because significant difficulties have been reported in children with ADHD (Harvey & Reid, 2003). Motor skills difficulties have been related to limited participation in physical activity (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996). Thus, improvement in motor skills could be an important variable facilitating the sport participation for those children.

It could be surprising to note that two of the most important fitness parameters, aerobic fitness level and body composition, did not differ after the program. Results of longitudinal studies in children have suggested that training has no effect on $VO_2$ peak, a parameter usually associated with aerobic capacity, before puberty (Rowland, 1985). In a review published in 2003 (Baquet, Van Praagh, & Berthoin), mean gains reported were less than 10% in $VO_2$ peak. It was indicated that potential moderators such as maturity, gender, initial aerobic level, physical activity level, testing modality, or dropout rate could influence the responses of the aerobic capacity to training. Authors found that two or more sessions per week with an intensity higher than 80% of maximal HR were necessary to expect a significant improvement in the $VO_2$ peak in a children population. Similarly, only small changes in body composition (1%-3% body fat) have been reported, and mostly when interventions were oriented on longer duration, lifestyle activities (Bar-Or & Baranowski, 1994) and combined with appropriate dietary changes (Epstein, Meyers, Raynors, & Saelens, 1998; Southern, 2001). In this study, the program was designed to offer optimal improvement: Intensity was carefully monitored to about 77% of maximal HR, frequency was adequate, and duration was long enough to expect changes. However, initial levels of aerobic capacity and body composition of participants were in an optimal range, and many moderators such as nutrition status or physical activity practice have not been addressed. It could be interesting to consider separately the changes in overweight or obese participants, but small samples limit statistical analysis.

Previous studies have found a positive relationship between diverse parameters of cognition and aerobic fitness tests (Buck et al., 2007; Castelli et al., 2007; Dwyer et al., 2001) or moderate-to-vigorous physical activity (Coe et al., 2006). This study found no significant differences for the inhibition deficit and impaired characteristics of hyperactivity-impulsivity associated with ADHD. Thus, this program did not affect all the ADHD core symptoms. Nevertheless, it had a significant impact on information processing and on other important functional domains such as social skills and behavior. After the program, higher scores in behavior and attention functions were present in the experimental group without changes in the aerobic fitness level. Thus, they could be related to participation in the moderate-to-vigorous physical activity program.

A main finding of this study is that both parents and teachers observed better behavioral scores in the physical activity group. This could mean that positive effects of physical activity may occur in different settings of the children's life. Indeed, though the changes were different for parents and teacher CBCL scales, the scores achieved by the physical activity group on the social scale were significantly higher after the conclusion of the program for both types of respondents. This could be very interesting because children with ADHD frequently have to deal with social difficulties and isolation (Antshel & Remer, 2003), and convincing evidence for social relationship programs efficacy is still lacking (Frankel, Myatt, Cantwell, & Feinberg, 1997; Pelham & Fabiano, 2008). Interestingly, the Summer Treatment Program (STP), which includes various strategies in behavioral modification, uses sport group activities to give an opportunity for children with ADHD to practice appropriate behaviors and social relations. This form of behavioral intervention is proposed as one of the efficient treatments for ADHD children (Pelham & Fabiano, 2008). However, present results suggest that physical activity by itself could help to improve social behavior.

Finally, another central feature of the present study is that attention improvement has been measured by two different assessment procedures. Indeed, parental report of attentional behavior and standardized measure of attention are convergent indices of the positive effect of physical activity on the attention function of children with ADHD. Specifically, it seems that children with ADHD in the experimental group were more efficient in information processing as shown by faster speeds of visual research and better sustained auditory attention. Attention has previously been associated with high aerobic fitness level in healthy preadolescents, but the variables used were the speed of reaction and the amplitude of the P3 component of the event-related brain potentials, which are hypothesized to be an indicator of the processes involved in the allocation of attention and working memory (Hillman et al., 2005). Present results add some support to the effect of physical activity on this cognitive domain. To our knowledge, no other study has looked at physical activity and sustained auditory attention in children.

## Limitations

Some methodological issues must be discussed. Indeed, due to recruitment difficulties, participants in the experimental group were recruited in the same school, whereas the control group children were recruited from different areas. Moreover, there was a difference in stimulant medication prescription between both groups. Those methodological issues are considered as minimal because groups were similar for fitness, behavior, and neuropsychological variables before the program. In addition, severity of the symptoms is only one variable influencing parental decision to give medication to their children, but several other factors such as adverse effects, apprehensions about stigmatization, and the child's dislike of taking pills contribute to parents' decisions to suspend or not adhere to medication (Charach, Skyba, Cook, & Antle, 2006). Another limit to the generalization of these results is that both parents and teachers were aware of the treatment and probably had expectations for changes. The expectancy, or the Halo effect, could influence the positive response in physical activity and cognition studies (Shepard, 1997). Objective measurement of behaviors, such as direct observation or a placebo control group, could be a good way to eliminate this bias in further studies. Finally, the small sample used in the study and missing data in some cases limit the statistical power of the study. Thus, the results must be considered as preliminary and will have to be replicated. However, they can be useful to guide future research.

## Conclusion

Thus, despite positive results, conclusions must be considered as exploratory, due to methodological issues. Nevertheless, results suggest that a physical activity program may be beneficial for children with ADHD. In addition to strength and motor skills, it positively influences behaviors and cognitive function such as attention in children with ADHD. In order to add support to those outcomes, future research should include greater executive functions assessment. Moreover, follow-up and additive effects of others therapies should be explored.

In conclusion, the present study has important clinical implications. Considering the beneficial effect of physical activity participation on some important ADHD-related variables, schools and parents of children with ADHD should look to maximize opportunities for structured group physical activity in their children's life.

### Acknowledgment

We wish to thank the participants and their parents as well as students from the Department of Kinesiology at the University of Montreal who contributed to this work.

### Declaration of Conflicting Interests

The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

### Financial Disclosure/Funding

The authors received no financial support for the research and/or authorship of this article.

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