

# **Fitness Level and Gross Motor Performance of Children With Attention-Deficit Hyperactivity Disorder**

**Claudia Verret**

Hôpital Rivière-des-Prairies and Université de Montréal

**Phillip Gardiner**

University of Manitoba

**Louise Béliveau**

Université de Montréal

The purpose of this study was to assess fitness and gross motor performance of children with ADHD, including users and nonusers of methylphenidate medication. Seventy boys took part in the study. Fitness level of children with ADHD using medication or not, including body composition, flexibility, and muscular endurance, was similar to that of a control group. The only difference was observed for body mass index, which was lower in children with ADHD using medication. Aerobic capacity was also similar when measured by a treadmill test. A lower performance was observed when aerobic capacity was estimated using a field shuttle test, however, suggesting that the methodology used is important. Finally, both groups of children with ADHD presented significantly lower scores for locomotion skills.

Attention-deficit hyperactivity disorder (ADHD) is one of the most prevalent disorders in children (American Psychiatric Association, 2000). It is characterized by inattention, hyperactivity, and/or impulsivity and has a negative impact in many areas of children's life (APA, 2000). In a classical theoretical model of ADHD, inhibition has been proposed as the principal deficit of this disorder (Barkley, 1997). This inhibition deficit is thought to alter the efficiency of four executive neuropsychological functions: working memory, self-regulation of affect, internalization of speech, and reconstitution. This model predicts that such inhibition and executive functions difficulties have a negative impact on motor control. Indeed, links between ADHD and motor problems have been proposed (Beyer, 1999; Harvey &

---

Claudia Verret is with the Rivière-des-Prairies Hospital and the Department of Kinesiology at the Université de Montréal. Phillip Gardiner is with the Faculty of Kinesiology and Recreation Management and Faculty of Medicine at the University of Manitoba in Winnipeg, Canada. Louise Béliveau is with the Department of Kinesiology at the Université de Montréal.

Reid, 1997, 2003; Pitcher, Piek, & Hay, 2003). As motor skills are an important determinant of physical activity and fitness (Bouffard, Watkinson, Thompson, Causgrove Dunn, & Romanow, 1996; Malina, 1990), it could be hypothesized that children with ADHD may also have a low fitness level. Few authors have described fitness levels in children with ADHD, however, and available results from previous studies are divergent.

Fitness assessment is a complex task because it is defined by several parameters. Moreover, the body of literature is predominantly composed of adult studies and there is a lack of information in children of the general population (Malina, Bouchard, & Bar-Or, 2004). Nevertheless, body composition, muscular and aerobic capacities, as well as flexibility are the predominantly used variables to assess global fitness in children. Given the importance of motor skills for the level of physical activity in the child population, it also has been suggested to include these skills in fitness assessment (Malina, 1990).

There is considerable variation in the conclusions of studies on fitness and ADHD. Differences are reported between variables of body composition, aerobic capacity, and motor skill assessment. Methodological differences, diversity of assessment protocols, and method of data comparison could be potential explicative factors (Harvey & Reid, 2005). Moreover, a clear definition of the diagnosis and comorbidities of the participants are sometimes missing. Finally, medication could also be a confounding factor in previous studies (Harvey & Reid, 2005). In most available studies, researchers have examined fitness in children who were using stimulant medication, or have reported combined results for users and non users of medication.

Those methodological issues are present in the research looking for relationships between body composition and ADHD. For instance, body composition has been assessed by different skinfold protocols or by body mass index (BMI) calculation, and data were compared with norms or control group. Researchers using skinfold assessment have reported that children with ADHD taking medication had an equal or a higher sum of skinfolds compared with a control group (Tantillo, Kesick, Hynd, & Dishman, 2002) or to norms (Harvey & Reid, 1997). Similarly, some authors found that children with ADHD had higher BMI than norms (Holtkamp et al., 2004) or a control group (Hubel, Jass, Marcus, & Laessle, 2006). Other researchers using BMI, however, have found that the prevalence of overweight and obesity was similar to aged-matched population norms (Curtin, Bandini, Perrin, Tybor, & Must, 2005) or to a control group (Wigal et al., 2003). Some authors suggest a potential difference in BMI between children with ADHD users and non users of methylphenidate. Indeed, Curtin et al. (2005) found that proportion of overweight was reduced in half in children with ADHD taking stimulants compared with those not using medication; however, this difference was not observed in other studies (Holtkamp et al., 2004).

The impact of medication on growth rate has been the object of several studies because it has been suggested that medication could negatively affect growth of children with ADHD (Poulton, 2005). Indeed, some growth retardation has been reported in children with ADHD during stimulant treatment (Charach, Figueroa, Chen, Ickowicz, & Schachar, 2006; Poulton, 2005; Swanson et al., 2007), but other authors suggest no clinical impact of stimulant therapy on growth rate (Biederman et al., 2003; Pliszka, Matthews, Braslow, & Watson, 2006; Spencer et al.,

2006; Sund & Zeiner, 2002). Methodology, dose range, duration of treatment, or compliance with the drug treatment could explain the different conclusions (Sund & Zeiner, 2002). In a review on the effect of stimulant medication on growth, Poulton (2005) reported that a clear relationship between stimulant treatment and height deficit has been shown in high quality studies. An attenuation of growth in weight can also be related to appetite suppression at the initiation of treatment and a return to normal score within a few months is usually observed (Poulton, 2005). Considering the divergent results of the previous papers on body composition or growth rate, impacts of those fitness determinants in children with ADHD with or without medication are not fully established.

Discrepancies in assessment protocol and results also arise when comparing aerobic capacity parameters. Harvey and Reid (1997) have found that children with ADHD using medication had a lower aerobic capacity, as measured by a shuttle run test, when compared with standard norms. These results differ from those of other authors who have used a treadmill protocol for testing aerobic capacity. For instance, Ballard (1977) as well as Tantillo et al. (2002) have shown that children with ADHD taking stimulant medication had an aerobic capacity similar to that of a control group. The authors did not include children with ADHD who did not take medication. One study reporting aerobic capacity in untreated children with ADHD used a progressive cycle ergometer test (Wigal et al., 2003). The authors did not find differences in the peak oxygen consumption compared with a control group. There is not enough evidence in the scientific literature to establish clear conclusions on aerobic capacity in children with ADHD.

A deficit in motor skills, in addition to potentially affecting results from a specific test, could also explain some of the differences in fitness-related variables. Indeed, the optimal development of motor skills can facilitate positive physical activity behaviors and support the exercise practice levels required for better fitness (Okely, Booth, & Patterson, 2001). Prevalence of motor problems in children with ADHD varies between 8 and 52% across studies (Barkley, 1990; Doyle, Wallen, & Whitmont, 1995). Differences in methodology could be an explanation for this wide range (Harvey & Reid, 2005; Steger et al., 2001). According to Harvey and Reid (2003), the term motor coordination may be misleading and there may have been considerable confusion between fine and gross motor skills definition and assessment. Some researchers have investigated motor performance (Beyer, 1999; Harvey & Reid, 1997; Piek, Pitcher, & Hay, 1999; Pitcher, Piek, & Hay, 2003; Tseng, Henderson, Chow, & Yao, 2004), motor dysfunction (Tervo, Azuma, Fogas, & Fiechtner, 2002), neuromotor deficits (Steger et al., 2001) or coordination problems (Denckla & Rudel, 1978). Most of the tasks assessed in those papers are quite different from those completed in a physical activity context. Harvey and Reid (2003) have suggested that most researchers evaluating motor performance should describe children with ADHD as having poor fine motor coordination rather than a general motor coordination deficit. In a literature review looking specifically at gross motor skills in children with ADHD, these authors concluded cautiously that children with ADHD could be more at risk for movement skill problems than aged-matched peers without ADHD. Although there is converging evidence of movement difficulties in children with ADHD, there is a scarcity of information on their relation with fitness-related variables, rendering conclusions difficult.

The aim of this study is to compare physical fitness, motor performance in gross motor skills of locomotion and object control, and aerobic capacity, as assessed by a laboratory and a field test, in three groups of children: ADHD with stimulant medication, ADHD without medication, and a control group.

## Method

### Participants

Seventy boys (range from 7 to 12 years old) took part in the study. They were recruited in a specialized ADHD clinic of the Rivière-des-Prairies Hospital and the surrounding community. All participants presented combined subtype with the exception of four children (2 in both ADHD group), who had hyperactive-impulsive subtype. The children who presented an ADHD inattentive subtype, learning disorder, autism, Tourette's syndrome, intellectual disabilities, epileptic disorders, or who took medication other than methylphenidate were excluded from the study. The project was approved by the Research Ethics Committee of the Rivière-des-Prairies Hospital. Informed consent was provided and signed by parents.

### Diagnosis

All the participants presenting behaviors associated with the disorder had previously received an ADHD diagnosis according to the DSM-IV-TR criteria (American Psychiatric Association, 2000) by their pediatrician. They were evaluated individually in neuropsychology and psychiatry to validate the preliminary diagnosis and to specify the differential diagnosis. For details of this evaluation, see Guay, Lageix, and Parent (2006). For the control group, screening questionnaires completed by the parents were used to ensure that the children did not show characteristics associated with ADHD (Du Paul, Power, Anastopoulos, & Reid, 1998; Goodman, 1997). Three groups were formed: a control group of 27 children not presenting characteristics associated to ADHD, a group of 24 children with an ADHD diagnosis and taking stimulant medication (Ritalin or Concerta for an average  $24 \pm 19$  months; range between 5 and 72 months, median 21 months) and a group of 19 children presenting an ADHD diagnosis but never having used medication. It was not possible to assess dosage level because of missing data. Among the children taking medication, 58% did not have any comorbidity, 29% had one comorbidity (opposition or anxiety) and 13% had two comorbidities (anxiety, opposition, or obsessive-compulsive disorder). Among the children with an ADHD diagnosis not taking medication, 63% did not have any comorbidity and 37% had one comorbidity (opposition or anxiety).

### Fitness and Motor Tests

The participants performed the fitness and motor performance tests following the counterbalance method with the order of the sessions randomly assigned. In one session, the tests were body composition and musculoskeletal aptitudes (Canadian Society for Exercise Physiology, CSEP, 1998) as well as Bruce treadmill protocol. During the other session, the children completed the Test of Gross Motor

Development-2 (TGMD-2; Ulrich, 2000) and the Shuttle test of Léger, Lambert, Goulet, Rowan, and Dinelle (1984). The participants were informed not to practice intense physical activity and to cease any medication on the day preceding the assessments. Height, weight, body mass index (BMI), flexibility, muscular endurance, resting heart rate, as well as resting systolic and diastolic blood pressure (SBP/DBP) were measured. Height and weight norms were provided by the CSEP (Docherty, 1996). The most recent growth norms provided by the U.S. Centers for Disease Control and Prevention (National Center for Chronic Disease Prevention and Health Promotion, CDC, 2000) were used to transform BMI raw scores to percentiles. Skinfold thicknesses were measured in duplicate (Bionetic Skinfold Caliper). The fat percentage was estimated from the measurement of 4 skinfolds (biceps, triceps, subscapular, and supra-iliac) using a formula suitable for children (Westrate & Deurenberg, 1989). Flexibility was measured with the Sit and Reach test. Data on muscular endurance was 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). Heart rate was measured by a heart rate monitor (Polar S-810) and blood pressure with a medical blood pressure monitor (Colin Company Instruments Corp).

Aerobic capacity was measured using two protocols. For the Bruce maximal progressive treadmill test, running time and percentile of the aerobic performance were assessed. 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. Percentiles were obtained by comparing running time with norms (Wessel, Strasburger, & Mitchell, 2001). The 20-m shuttle run test is a maximal progressive field test which has been used extensively to assess the aerobic fitness of children (Léger et al., 1984). Number of stages completed, percentile of aerobic performance, and maximal heart rate were measured. Percentiles were obtained from the test norms. All shuttle tests were done with a running collaborator to provide a model to the children to ensure reaching of required running speed during each stage.

Gross motor skills were assessed using the TGMD-2 (Ulrich, 2000). This test is subdivided in two parts: locomotor and object control skills. The 12 tasks were run, gallop, hop, leap, horizontal jump, skip, and slide for the locomotion as well as two-hand strike, stationary bounce, catch, kick, overhand throw, and underhand roll. Participants performed the test as described in the TGMD-2 Examiner's Manual. All tests were recorded and judged by different blind experimenters. An interjudge agreement was calculated and experimenters made a regular follow-up of their assessment's skills using a standardized video. Scores were calculated from the sum of two trials of each subtest. A score of 0 indicated that the participant performed a component incorrectly. Maximal possible score for locomotion and object control is 48. Raw scores are presented for the locomotion and object control skills.

## Statistical Analysis

Parametrics assumptions were established using visual inspection of the data, the Kolmogorov-Smirnov procedure for normality of sampling distribution and Levene's test for homogeneity of variance. Differences between groups were tested following a three-step process. First, sets of independent variables were tested globally

using multivariate analysis of variance (MANOVA). Then, individual independent variables were tested separately using univariate analysis of variance (ANOVA). Third, where a significant ANOVA result was found, the Tukey multiple comparisons test was used. Effect sizes were calculated by using the eta-squared ( $\eta^2$ ) formula (Cohen, 1973). Statistical significance for the two-tailed tests was set at  $p < .05$ . Complementary analyses were conducted to look for a difference in the aerobic test performance. A paired  $t$  test was executed on the percentile obtained in both aerobic tests. Finally, Chi-square tests were used to look for differences between groups as for rate of BMI percentile classified as at risk (overweight and obese). Analyses were run using SPSS 10.0.

## Results

### Anthropometrical, Body Composition and Fitness Variables

A global significant difference was obtained for the set of body composition variables and anthropometrical variables,  $F(12, 126) = 1.984, p = 0.031$ . Indeed, the BMI and the BMI percentile were significantly different between the groups (Table 1); however, no individual differences were found among the anthropometrical variables (Table 1). The Tukey test of multiple comparisons indicated that children in the ADHD group with medication have a significantly lower BMI than children in the control group ( $p = 0.012$ ). They also showed a tendency to have lower BMI than the ADHD group without medication ( $p = 0.097$ ). Children in the ADHD with medication group also have a significantly lower BMI percentile than the control group ( $p = 0.002$ ) and the ADHD without medication group ( $p = 0.002$ ). Effect sizes were 0.122 for BMI and 0.201 for BMI percentile (Table 1). Using Cohen's

**Table 1 Means and Standard Deviations of Anthropometrical and Body Composition Variables**

Variable	Control		ADHD and Medication		ADHD no Medication		One-Way ANOVA Test		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i> ( <sub>2,67</sub> )	<i>p</i>	<i>ES</i>
Age (yrs)	9.7	1.3	10.0	1.1	9.4	1.5	1.061	0.352	0.031
Weight (kg)	34.1	6.3	31.1	6.9	34.0	8.2	1.433	0.246	0.041
Height (m)	1.35	0.1	1.35	0.1	1.37	0.1	0.305	0.738	0.009
Body mass index	18.7	2.8	16.7	2.2	18.3	2.3	4.663	0.013 <sup>†</sup>	0.122
Percentile									
BMI	68.6	24.9	42.8	26.5	70.8	26.4	8.442	0.001 <sup>†‡</sup>	0.201
% Fat	19.9	6.4	15.9	5.4	18.9	6.4	2.986	0.057	0.082

*Note.* BMI: Body Mass Index; <sup>†</sup> ADHD with medication significantly different from control group; <sup>‡</sup> ADHD with medication significantly different from ADHD no medication group; ES = effect size = proportion of observed variance attributed to differences between the groups.

(1988) guidelines for interpreting the amount of explained variance, this would be considered as a medium and a large effect.

There were no significant differences for the set of fitness variables, neither globally,  $F(12, 114) = 1.291, p = 0.234$ , nor individually (Table 2).

The result of the Chi-square test for three independent samples indicates differences of BMI classification between groups,  $\chi^2(2) = 8.731, p = .013$ . The group of ADHD with medication had a higher proportion of normal BMI (92%) compared with control group (63%) and ADHD no medication group (53%).

**Table 2 Means and Standard Deviations of Fitness Variables**

Variable	Control		ADHD and Medication		ADHD no Medication		One-Way ANOVA Test		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i> <sub>(2,61)</sub>	<i>p</i>	<i>ES</i>
Push-ups (#)	13.0	5.9	8.8	6.4	11.7	8.8	2.156	0.125	0.066
Sit-ups (#/60s)	33.2	7.5	32.1	14.5	29.8	14.7	0.410	0.666	0.013
Flexibility (cm)	25.9	4.5	22.1	7.2	23.9	5.3	2.258	0.113	0.069
Resting heart rate (b/min)	80.8	12.0	85.4	14.7	84.8	13.8	0.776	0.465	0.025
Systolic blood pressure (mmHg)	110.0	9.3	107.1	9.6	107.0	11.3	0.618	0.542	0.020
Diastolic blood pressure (mmHg)	64.6	7.1	67.7	7.9	64.2	8.4	1.291	0.282	0.041

Note. ES = effect size = proportion of observed variance attributed to differences between the groups.

**Table 3 Means and Standard Deviations of Aerobic Capacity Variables**

Variable	Control		ADHD and Medication		ADHD no Medication		One-Way ANOVA Test		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i> <sub>(2,38)</sub>	<i>p</i>	<i>ES</i>
Bruce									
Running time (min)	12.4	3.4	10.7	2.7	10.5	2.5	1.677	0.200	0.081
Percentiles	70.0	34.2	57.7	27.1	58.0	28.1	1.994	0.150	0.095
Léger									
Stage (#)	3.3	1.4	2.9	1.8	2.0	0.9	1.150	0.327	0.057
Percentiles	15.9	14.3	15.4	21.9	6.0	8.6	0.762	0.474	0.039

Note. ES = effect size = proportion of observed variance attributed to differences between the groups.

## Aerobic Capacity Variables

MANOVA test indicates globally no significant difference between groups for the set of aerobic capacity variables,  $F(8, 72) = 0.976, p = 0.462$ .

A second interesting result was obtained when comparing the percentiles reached by all participants in both running protocols. Result of the paired  $t$  test suggests that participants performed significantly better at the Bruce treadmill protocol than at the field test of Léger,  $t(40) = 9.91, p = .000$ . In the Bruce protocol, the participants had a mean performance in the higher average compared with available norms. In the shuttle test, however, the mean performance was under the average.

## Gross Motor Variables

MANOVA result indicates a significant difference for motor performance variables,  $F(4, 126) = 4.198, p = 0.003$ . A significant difference was observed only for the locomotion variable (Table 4). The Tukey test of multiple comparisons indicated that both groups of children with ADHD had lower scores for the locomotion component compared with children of the control group ( $p = .005$  for ADHD with medication group and  $p = .022$  for ADHD without medication group). Effect size for locomotion was 0.167 (Table 4). Using Cohen's (1988) guidelines this would be considered as a large effect.

**Table 4 Means and Standard Deviations of Gross Motor Variables**

Variable	Control		ADHD and Medication		ADHD no Medication		One-Way ANOVA Test		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i> <sub>(2,63)</sub>	<i>p</i>	<i>ES</i>
Locomotion	43.4	3.1	38.9	5.9	39.5	4.6	6.293	0.003 <sup>†*</sup>	0.167
Object control	41.3	4.8	41.9	4.9	40.2	5.3	0.618	0.542	0.019

*Note.* <sup>†</sup> ADHD with medication significantly different from control group; \* ADHD no medication significantly different from control group; ES = effect size = proportion of observed variance attributed to differences between the groups.

## Discussion

The main objectives of this study were to compare the fitness and motor performance of children with ADHD taking medication or not with those of children without the deficit. Specific care was taken to ensure that children with ADHD included in the study had received a reliable psychiatric diagnosis. Indeed one of the pitfalls of published data on children with ADHD appears to be the method of diagnosis, which can vary from parents' assessment by questionnaires to medical or psychiatric evaluations (Beyer, 1999; Harvey & Reid, 2003; Piek et al., 1999; Pitcher et al., 2003; Tseng et al., 2004). Furthermore, many previous studies did not take medication use into consideration or did not include a control group (see Harvey & Reid, 2005) as was the case in this study. Moreover, two aerobic capacity assessment protocols were compared to try to explain the differences found in previous works. Finally, authors tried to control for the homogeneity of the sample.



Indeed, Kooistra, Crawford, Dewey, Cantell, and Kaplan (2005) showed that motor deficiency associated with ADHD and learning disorders is higher in comparison with an ADHD only group or a control group. In addition, some results suggest that children with the ADHD inattentive subtype (Piek et al., 1999) or hyperactive-impulsive subtype (Pitcher et al., 2003) could have motor performances different from those with the ADHD combined subtype. Small samples limit the generalization of previous results and the need for more research has been suggested (Harvey & Reid, 2005). For that reason, care was taken to control heterogeneity of the sample by including children with ADHD having the combined subtype and by excluding children with ADHD presenting comorbidities other than anxious and oppositional disorders and children presenting learning disorders.

## Implications

In the measured fitness-related variables, body composition is the only parameter which differed significantly between groups. Children with ADHD taking medication had a smaller BMI than the control group and a smaller BMI percentile than the two other groups. This result is in agreement with the growth retardation often reported in children with ADHD during stimulant treatment (Charach et al. 2006; Poulton, 2005; Swanson et al., 2007). Although there are discrepancies in results from published studies and on the clinical impact of such growth attenuation, the available evidence does suggest its presence and the importance of dosage and time of prescription. In this study, there is no difference in weight and height between groups, but the lack of information on dosage and time of prescription limits further analysis. Furthermore, when compared with population norms, the mean BMI percentiles are slightly under the average for children with ADHD taking medication and in the higher average for the two other groups (CDC, 2000). Moreover, all participants presented a fat percentage within the "optimal" category (Westrate & Deurenberg, 1989), suggesting that the participants had a normal body composition. On the other hand, the proportion of overweight and obesity was higher in the group of children with ADHD no medication and in the control group compared with Canadian prevalence of overweight (29%) and obesity (14%) for boys (Tremblay & Willms, 2000). As suggested by Willms (2004), several issues concerning the measurement of body fat and the definition of overweight and obesity in childhood are unanswered. Moreover, mechanisms related to weight gain could differ between populations. Indeed, some authors have found a large prevalence of children and adults with ADHD in weight management programs, and tentatively proposed ADHD mechanisms such as impulsivity to explain this large representation (Agranat-Meged et al., 2005; Altfas, 2002).

Harvey and Reid (1997) have assessed other variables of physical fitness and compared them with the Canadian standard norms of 1985. Almost all children in their sample took medication but the small number of participants in their study contraindicated separation of the groups. They reported that those children were below average for flexibility and push-ups and were poor for sit-ups, compared with norms of an age-matched population (Fitness Canada, 1985). In the current study, there were no significant differences among groups for any muscular-related variables. A comparison with 1985 standards, however, also points to a lower fitness for all the groups in this study. Unfortunately, there are no recent Canadian standard norms to compare these fitness determinants.

The comparison of the three groups included in the current study shows similar running times for the Bruce laboratory test and similar number of completed stages in the shuttle field test of Léger. In the Bruce protocol, a comparison with norms (Wessel et al., 2001) indicates that children of all three groups were in a high average category compared with an age-matched population. The comparison of number of stage with the standard norms of Léger et al. (1984) showed that all groups of children had performances lower than average. This is similar to results from Harvey and Reid (1997), who reported maximum aerobic power results lower than average by comparing their results to the same norms. This could be related to the use of standard norms established in 1984. Tomkinson, Léger, Olds, and Carzola (2003) have published a meta-analysis comparing the performance of children and adolescents of 6–19 years on the 20 m shuttle test from 1981 to 2000. They showed a decline of 0.43% of mean values per year. In the current study, no difference between ADHD and control group was observed for the shuttle test. It should be noted that all running tests were done with a running collaborator, providing a model to the children to ensure running speed. Indeed, the objective of the test was to assess aerobic fitness, not the children's understanding of the procedure. Clinical observations do suggest, however, that children with ADHD have difficulties in adjusting rhythm and respecting a pace imposed by the test. Difficulties in self-regulation of movement and impaired sense of time have been linked to children with ADHD (Harvey et al., 2007).

Locomotion, as measured by the TGMD-2, is the only variable for which children with ADHD differed from children without the deficit, with lower raw scores for both groups of children with ADHD than for the control group. Previously, researchers have also suggested that children with ADHD are at risk for developing motor problems (Harvey & Reid, 2003). For example, using the TGMD, Harvey and Reid (1997) classified 19 children with ADHD using medication in the average category for object control skills and under average for locomotion skills. Zhang (2001) obtained similar results for a small sample of children with ADHD and for a group of children with learning disorders. On the other hand, Doyle and collaborators (1995) reported that only 5% of children with ADHD in their sample (total  $n = 38$ ) had substantial gross motor difficulties when assessed by the short form survey of Bruininks-Oseretsky Test of Motor Proficiency (BOTMP; Bruininks, 1978). Present results have been compared with recent norms included in the TGMD-2 protocol. They indicate that nearly half (47%) of the children with ADHD of both groups are below the 25th percentile, compared with only 21% of children in the control group. The 25th percentile is the clinically recognized cut-off where children need special services to help their deficits (Geuze, 2005).

One important finding is that no significant difference was measured in gross motor performance between children with ADHD taking medication or not (Table 3). This supports observations by Doyle et al. (1995), who did not report any difference between the BOTMP scores with or without medication. In a more recent and well controlled study, movement skills performance of 22 children with ADHD has been assessed using the TGMD-2 in a placebo-controlled design with a control group (Harvey et al., 2007). Children with ADHD had lower scores than the age-matched control group on both condition trials in the locomotor and object control subtests. However, no significant effects of medication on movement skills were found between medication and placebo trials. Earlier conclusions suggested

that medication (methylphenidate) influences the ability to maintain attention more than speed or gross motor control (Beyer, 1999; Pelham et al., 1990). Harvey et al. (2007) proposed that factors other than medication could explain some differences reported in the gross motor skills of children with ADHD. They suggested that lack of physical skills and experience, poor social skills, failure to regulate performance, comorbidity, motivation, and time constraints or performance conditions could be important factors but this still needs to be addressed (Harvey & Reid, 2005). Present results add support to the suggestion that medication did not influence the gross motor performance of children with ADHD. This is an important finding because few researchers have assessed motor performance in medication-treated and medication-free children with ADHD.

## Limitations

In this study, it was not possible to obtain precise data for dosage of medication. Because of this methodological issue, the impact of dosage and time of prescription on growth parameters could not be established. This represents a major limitation in the generalization of this result and will have to be addressed in future studies. Analyses were also limited by the available norms. More recent norms will be needed to allow a better comparison of fitness level of participants.

## Recommendations for Further Study

In this research, ADHD participants present motor skills problems but no difference in overall fitness variables compared with peers. Several determinants influence fitness level and motor development. Physical activity practice, sedentary behaviors, and nutrition are among those. It is known that children with ADHD have high levels of motor activity (Porrino et al., 1983), but rate of practice and engagement in physical activities are not known in these children. Besides, they live in greater social isolation, have a high frequency of sedentary behaviors such as television or computer viewing, as well as uncommon food consumption practices, which could have an impact on fitness (Curtin et al., 2005). Motor skills problems could be a barrier to exercise practice. An activity-deficit hypothesis has been proposed as an explanation for the movement performance difficulties in ADHD (Harvey & Reid, 2003). This hypothesis highlights the process by which many children with motor skills difficulties avoid participating in physical activities and such an activity deficit may add to their lack of skill. In the current study, authors did not examine the relationship between gross motor performance and fitness or the level of physical activity. Those are not known in children with ADHD and add to the need of research on physical activity, fitness, and ADHD.

In conclusion, results from this study suggest that fitness of children with ADHD, using stimulant medication or not, is comparable with that of children without the deficit. The choice of protocol for assessment and interpretation of aerobic fitness is important with a population of children with ADHD. Children with ADHD, whether using medication or not, have lower locomotion skills. In this study, the generalization of the results is limited by the lack of information on medication and by available norms. Those limitations will have to be addressed in future studies. Moreover, the impact of motor skills deficit on sport participation is still to be explored.

## Acknowledgments

We wish to thank Claude Berthiaume from the Research Center of the Hôpital Rivière-des-Prairies, for his contribution to the statistical analysis section. We also thank the participants and their parents as well as students from the Department of Kinesiology at the Université de Montréal who contributed to this work.

## References

- Agranat-Meged, A.N., Deitcher, C., Goldzweig, G., Leibenson, L., Stein, M., & Galili-Weisstub, E. (2005). Childhood obesity and attention deficit/hyperactivity disorder: A newly described comorbidity in obese hospitalized children. *The International Journal of Eating Disorders*, *37*, 357–359.
- Altfas, J.R. (2002). Prevalence of attention deficit/hyperactivity disorder among adults in obesity treatment. *BMC Psychiatry*, *13*(2) 9.
- American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders: DSM-IV-TR*. Washington, DC: American Psychiatric Association.
- Ballard, J.E. (1977). The effects of methylphenidate during rest, exercise, and recovery upon the cardiorespiratory responses of hyperactive children. *Microform Publications* (University of Oregon Library No. RM666.M545).
- Barkley, R.A. (1990). *Attention Deficit Hyperactivity Disorder: A handbook for diagnosis and treatment*. New-York: Guilford Publications.
- Barkley, R.A. (1997). *ADHD and the nature of self-control*. New York: Guilford Publications.
- Beyer, R. (1999). Motor proficiency of boys with attention deficit hyperactivity disorder and boys with learning disabilities. *Adapted Physical Activity Quarterly*, *16*, 403–414.
- Biederman, J., Faraone, S.V., Monuteaux, M.C., Plunkett, E.A., Gifford, J., & Spencer, T. (2003). Growth deficits and attention-deficit/hyperactivity disorder revisited: Impact of gender, development, and treatment. *Pediatrics*, *111*, 1010–1016.
- Bouffard, M., Watkinson, E.J., Thompson, L.P., Causgrove Dunn, J.L., & Romanow, S.K.E. (1996). A test of the activity deficit hypothesis with children with movement difficulties. *Adapted Physical Activity Quarterly*, *13*, 61–73.
- Bruininks, R.H. (1978). *The Bruininks-Oseretsky Test of Motor Proficiency*. Circles Pines, MN: American Guidance Service.
- Canadian Society for Exercise Physiology (CSEP). (1998). *Physical Activity, Fitness and Lifestyle Appraisal: CSEP's plan for healthy active living*. Ottawa, ON: Author.
- Charach, A., Figueroa, M., Chen, S., Ickowicz, A., & Schachar, R. (2006). Stimulant treatment over 5 years: Effects on growth. *Journal of the American Academy of Child and Adolescent Psychiatry*, *45*, 415–421.
- Cohen, J. (1973). Eta-squared and partial eta-squared in fixed factor ANOVA designs. *Educational and Psychological Measurement*, *33*, 107–112.
- Cohen, J. (1988). *Statistical analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.
- Curtin, C., Bandini, L.G., Perrin, E.C., Tybor, D.J., & Must, A. (2005). Prevalence of overweight in children and adolescents with attention deficit hyperactivity disorder and autism spectrum disorders: A chart review. *BMC Pediatrics*, *5*, 48–55.
- Denckla, M.B., & Rudel, R.G. (1978). Anomalies of motor development in hyperactive boys. *Annals of Neurology*, *3*, 231–233.
- Docherty, D. (1996). *Measurement in pediatric exercise science*. Ottawa, ON: Canadian Society for Exercise Physiology.
- Doyle, S., Wallen, M., & Whitmont, S. (1995). Motor skills in Australian children with attention deficit hyperactivity disorder. *Occupational Therapy International*, *2*, 229–240.

- Du Paul, G.J., Power, T.J., Anastopoulos, A.D., & Reid, R. (1998). *ADHD rating scale-IV: Checklists, norms and clinical interpretation*. New-York: Guilford Press.
- Fitness Canada. (1985). *Physical fitness of Canadian youth*. Ottawa, ON: Government of Canada, Fitness and Amateur Sport.
- Geuze, R.H. (2005). Caractéristiques du Trouble de l'Acquisition de la Coordination (TAC): à propos des difficultés et du pronostic d'évolution [Characteristics of the Development Coordination Disorder (CDC): Difficulties and evolution]. In R.H. Geuze, *Le trouble de l'acquisition de la coordination: Évaluation et rééducation de la maladresse chez l'enfant* [The Development Coordination Disorder: Evaluation and rehabilitation of clumsiness in children] (p. 9-27). Marseille, Éditions Solal.
- Goodman, R. (1997). The Strength and Difficulties Questionnaire: A research note. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 38, 581–586.
- Guay, M.-C., Lageix, P., & Parent, V. (2006). Proposition d'une démarche évaluative du TDAH. Coordination motrice, pratique de l'activité physique et TDAH [Proposal of an assessment procedure for ADHD]. Dans N. Chevalier, M.-C. Guay, A. Achim et P. Lageix & H. Poissant (Eds). *Trouble déficitaire de l'attention avec hyperactivité: Soigner, éduquer, surtout valoriser* [Attention-deficit/hyperactivity disorder: Treat, educate, and mainly understand] (p. 3-16). Québec: Presses de l' Université du Québec, collection *Santé et Société*.
- Harvey, W.J., & Reid, G. (1997). Motor performance of children with attention-deficit hyperactivity disorder: A preliminary investigation. *Adapted Physical Activity Quarterly*, 14, 189–202.
- Harvey, W.J., & Reid, G. (2003). Attention-deficit/hyperactivity disorder: A review of research on movement skill performance and physical fitness. *Adapted Physical Activity Quarterly*, 20, 1–25.
- Harvey, W.J., & Reid, G. (2005). Attention-deficit/hyperactivity disorder: APA research challenges. *Adapted Physical Activity Quarterly*, 22, 1–20.
- Harvey, W.J., Reid, G., Grizenko, N., Mbekou, V., Ter-Stepanian, M., & Jooper, R. (2007). Fundamental movement skills and children with attention-deficit hyperactivity disorder: peer comparisons and stimulant effects. *Journal of Abnormal Child Psychology*, 35, 871–882.
- Holtkamp, K., Konrad, K., Muller, B., Heussen, N., Herpertz, S., Herpertz-Dahlmann, B., et al. (2004). Overweight and obesity in children with attention-deficit/hyperactivity disorder. *International Journal of Obesity*, 28, 685–689.
- Hubel, R., Jass, J., Marcus, A., & Laessle, R.G. (2006). Overweight and basal metabolic rate in boys with attention-deficit/hyperactivity disorder. *Eating and Weight Disorders*, 11, 139–146.
- Kooistra, L., Crawford, S., Dewey, D., Cantell, M., & Kaplan, B.J. (2005). Motor correlates of ADHD: Contribution of reading disability and oppositional defiant disorder. *Journal of Learning Disabilities*, 38, 195–206.
- Léger, L.A., Lambert, J., Goulet, A., Rowan, C., & Dinelle, Y. (1984). Capacité aérobie des québécois de 6 à 17 ans – test navette de 20 mètres avec paliers de 1 minutes [Aerobic fitness of 6 to 17 year old Quebecers—20-meters shuttle test with 1-minute stages]. *Canadian Journal of Applied Sport Sciences*, 9, 64–69.
- Malina, R.M. (1990). Physical activity: Relationship to growth, maturation, and physical fitness. In C. Bouchard, R.J. Shephard, T. Stephens, J.R. Sutton, & B.D. McPherson (Eds.), *Exercise, fitness and health: A consensus of current knowledge* (pp. 918–930). Champaign, IL: Human Kinetics Publishers.
- Malina, R., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity* (2nd ed.). Champaign, IL: Human Kinetics.
- National Center for Chronic Disease Prevention and Health Promotion (CDC). (2000). Growth charts. Retrieved September 1, 2007, from <http://www.cdc.gov/growthcharts>

- Okely, A.D., Booth, M.L., & Patterson, J.W. (2001). Relationship of physical activity to fundamental movement skills among adolescents. *Medicine and Science in Sports and Exercise*, 33, 1899-1904.
- Pelham, W.E., McBurnett, K., Harper, G.W., Milich, R., Murphy, D.A., Clinton, J., et al. (1990). Methylphenidate and baseball playing in ADHD children: Who's on first? *Journal of Consulting and Clinical Psychology*, 58, 130-133.
- Piek, J.P., Pitcher, T.M., & Hay, D.A. (1999). Motor coordination and kinaesthesia in boys with attention deficit-hyperactivity disorder. *Developmental Medicine and Child Neurology*, 41, 159-165.
- Pitcher, T.M., Piek, J.P., & Hay, D.A. (2003). Fine and gross motor ability in males with ADHD. *Developmental Medicine and Child Neurology*, 45, 525-535.
- Pliszka, S.R., Matthews, T.L., Braslow, K.J., & Watson, M.A. (2006). Comparative effects of methylphenidate and mixed salts amphetamine on height and weight in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, 45, 520-526.
- Porrino, L.J., Rapoport, J.L., Behar, D., Sceery, W., Ismond, D.R., & Bunney, W.E. (1983). A naturalistic assessment of the motor activity of the hyperactive boys: I. Comparison with normal controls. *Archives of General Psychiatry*, 40, 681-687.
- Poulton, A. (2005). Growth on stimulant medication; clarifying the confusion: a review. *Archives of Disease in Childhood*, 90, 801-806.
- Spencer, T.J., Faraone, S.V., Biederman, J., Lerner, M., Cooper, K.M., & Zimmerman, B. (2006). Does prolonged therapy with long-acting stimulant suppress growth in children with ADHD? *Journal of the American Academy of Child and Adolescent Psychiatry*, 45, 527-537.
- Steger, J., Imhof, K., Coutts, E., Gundelfinger, R., Steinhausen, H., & Brandeis, D. (2001). Attentional and neuromotor deficits in ADHD. *Developmental Medicine and Child Neurology*, 43, 172-179.
- Sund, A.M., & Zeiner, P. (2002). Does extended medication with amphetamine or methylphenidate reduce growth in hyperactive children? *Nordic Journal of Psychiatry*, 56, 53-57.
- Swanson, J.M., Elliott, G.R., Greenhill, L.L., Wigal, T., Arnold, L.E., Vitiello, B., et al. (2007). Effects of stimulant medication on growth rates across 3 years in the MTA follow-up. *Journal of the American Academy of Child and Adolescent Psychiatry*, 46, 1015-1027.
- Tantillo, M., Kesick, C.M., Hynd, G.W., & Dishman, R.K. (2002). The effects of exercise on children with attention-deficit hyperactivity disorder. *Medicine and Science in Sports and Exercise*, 34, 203-212.
- Tervo, R.C., Azuma, S., Fogas, B., & Fiechtner, H. (2002). Children with ADHD and motor dysfunction compared with children with ADHD only. *Developmental Medicine and Child Neurology*, 44, 383-390.
- Tomkinson, G.R., Léger, L.A., Olds, T.S., & Carzola, G. (2003). Secular trends in the performance of children and adolescents (1980-2000). An analysis of 55 studies of the 20m shuttle run test in 11 countries. *Sports Medicine (Auckland, N.Z.)*, 22, 285-300.
- Tremblay, M.S., & Willms, J.D. (2000). Secular trends in the body mass index of Canadian children. *Canadian Medical Association Journal*, 163, 1429-1433.
- Tseng, M.H., Henderson, A., Chow, S.M., & Yao, G. (2004). Relationship between motor proficiency, attention, impulse, and activity in children with ADHD. *Developmental Medicine and Child Neurology*, 46, 381-388.
- Ulrich, D.A. (2000). *Test of Gross Motor Development-2*. Austin, Texas: Pro-ed Inc.
- Wessel, H.A., Strasburger, J.F., & Mitchell, B.M. (2001). New standards for the Bruce treadmill protocol in children and adolescents. *Pediatric Exercise Science*, 13, 392-401.
- Westrate, J.A., & Deurenberg, P. (1989). Body composition in children: Proposal for a method for calculating body fat percentage from total body density or skinfold-thickness measurements. *The American Journal of Clinical Nutrition*, 50, 1104-1115.

- Wigal, S.B., Nemet, D., Swanson, J.M., Regino, R., Trampush, J., Ziegler, M.G., et al. (2003). Catecholamine response to exercise in children with attention deficit hyperactivity disorder. *Pediatric Research*, 53, 756–761.
- Willms, J.D. (2004). Early childhood obesity: a call for early surveillance and preventive measures. *Canadian Medical Association Journal*, 171, 243–244.
- Zhang, J. (2001). Fundamental motor skill performances of children with add, ld and mmr- a pilot study. *Palaestra*, 7-9.