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Research in Developmental Disabilities 34 (2013) 40–45

Contents lists available at SciVerse ScienceDirect

Research in Developmental Disabilities

Motor profile of children with attention deficit hyperactivity disorder, combined type

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ARTICLE INFO

Article history:
Received 13 April 2012
Received in revised form 13 July 2012
Accepted 16 July 2012
Available online

Keywords:
Motor profile
Attention deficit hyperactivity disorder
Children

ABSTRACT

Objectives: The aim of this study was to assess the motor profile of children with attention deficit hyperactivity disorder (ADHD), combined type.
Method: The case group consisted of 34 treatment-naive, male patients, aged 7–11 years, who had been diagnosed with ADHD, combined type, without comorbidities (except oppositional defiant disorder). The control group was composed of 32 age- and gender-matched, typically developing children. The evaluation was made using the Motor Development Scale, which assessed global and fine motricity, balance, body scheme, and spatial and temporal organization.
Results: The results showed that the motor quotients in all areas studied were lower in the ADHD group than in the control group, although in most cases they represent normal values relative to the scale (53% were classified as having "normal medium" motor development, 29% "normal low", 9% "very low", 6% "normal high" and 3% as "lower"). Statistically significant differences between groups were observed in general motor age, general motor quotient, balance, spatial organization, and fine and global motricity.
Conclusion: Difficulties in motor performance were observed in the children with ADHD, combined type. The identification of such deficits may assist in the design of therapeutic protocols for the treatment of children with this type of ADHD.

1. Introduction

Attention deficit hyperactivity disorder (ADHD) is characterized by the inappropriate development of activity level, low tolerance for frustration, impulsivity, distractibility, and the inability to sustain attention and concentration. *Inattentiveness* is the limited ability to remain attentive for the time needed to perform or understand a certain task; *hyperactivity* is characterized by excessive motor activity and impulsiveness in children, and is manifested in sudden and unthinking reactions. Both accompany ADHD (APA, 2000; Barkley, 2003).

ADHD is the most common neurobehavioral disorder during childhood, affecting approximately 3–6% of school-aged children (Polanczyk, Lima, Horta, Biederman, & Rohde, 2007; Rohde & Halpern, 2004). The estimated prevalence of ADHD worldwide is 5.29%. It occurs more often in boys than in girls, and commonly presents comorbidity with other neurological and psychiatric diseases (Barkley, 2003; Polanczyk et al., 2007). A substantial proportion (approximately half) of clinic-referred children with ADHD also are affected by oppositional defiant disorder (ODD) (APA, 2000).

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http://dx.doi.org/10.1016/j.ridd.2012.07.014

According to criteria specified in the Diagnostic and Statistical Manual of Mental Disorders, 4th edition, text revision (DSM-IV-TR), ADHD is subdivided into three types: *predominantly inattentive*, *predominantly hyperactive/impulsive*, and the *combined type* (which includes symptoms of both inattention and hyperactivity/impulsivity). The combined type is the most prevalent, and it presents greater impairment to overall functioning than do the other two types (APA, 2000; Rohde & Halpern, 2004).

To date, numerous investigations have described the neurobiological bases of ADHD. Morphometric and neuroimaging studies have identified the brain regions with abnormalities in individuals with this disorder. The main changes found in children are reductions in volume of the prefrontal cortex, the caudate nucleus, the globus pallidus, the anterior cingulate, and the cerebellum, mainly in the vermis and inferior posterior lobe (Berquin et al., 1998; Valera, Faraone, Murrayc, & Seidman, 2007).

Shaw et al. (2007) characterized a delay in the cortical maturation of patients with ADHD by comparing 223 children and adolescents with the disorder, and 223 typically developing children (control group). The aim of this study was to define the trajectory of cortical development using a measure of cortical thickness. The delay was most prominent in the prefrontal regions important to the control of cognitive processes, including attention and motor planning.

Children with ADHD not only display hyperactive motor behavior, but half of them, also, are clumsy when executing motor skills (Pitcher, Piek, & Hay, 2003). Motor problems can have a severe impact on children's daily lives, and occur in 30–50% of children with ADHD (Fliers et al., 2009; Visser, 2003). Unrest, marked by a continuous exchange of activities, can lead to problems with academic performance, and in difficulties with social relations. For example, excessive activities such as unnecessary body movements, impulsivity, anticipating responses, and the inability to wait for particular events can cause learning disabilities and motor disorders, which may result in school failure (Goulardins, 2010; Toniolo, Santos, Lourenceti, Padula, & Capellini, 2009). The aim of the current study, therefore, was to assess the motor profile of children with ADHD, combined type.

2. Materials and methods

2.1. Subjects

A cross-sectional study was conducted on 34 treatment-naive, male patients, aged 7–11 years, with clinical diagnoses of ADHD, combined type, according to classification criteria in the DSM-IV-TR, and without comorbidities, except ODD (comorbidity with ODD was not an exclusion criterion for this study due its high frequency in children with ADHD). These inclusion criteria were chosen in order to maintain homogeneity of the samples. The children were being treated by a multidisciplinary team, and follow-up treatment was being provided in the ADHD Clinic of the Pediatric Neurology Department, Central Institute and Learning Disorders Clinic, Institute for Children, Hospital of the Faculty of Medicine, University of Sao Paulo (HCFMUSP), Brazil.

The control group was composed of 32 age- and gender-matched, typically developing children from public schools. The exclusion criteria were mental retardation; visual, hearing, heart, rheumatic, orthopedic, neurological, and severe behavioral disorders; and regular use of medication.

Written consent was obtained from the parents and/or caregivers of all participants, and the study was approved by the Ethics Committee of the University of São Paulo Faculty of Medicine (no. 0573/08).

2.2. Procedures

Children with ADHD were identified via an initial screening process, in which their teachers and parents were asked to complete the SNAP-IV questionnaire. An expert pediatric neurologist then submitted these children to further assessment, using DSM-IV-TR criteria. From these diagnoses, ADHD types were identified. Once we confirmed the ADHD diagnosis, ADHD subtype, and absence of comorbidities (except ODD), all patients were further assessed by the main researcher. In order to ensure that we selected children for the control group free of symptoms of hyperactivity, impulsiveness, or inattention, we based our inclusion criteria on the information provided by parents in the SNAP-IV questionnaire.

The Motor Development Scale (MDS), described by Rosa Neto (2002), was used to assess fine and global motricity, balance, body scheme, and spatial and temporal organization. The MDS includes specific tasks designed for specific ages, ranging from 2 to 11 years, and complexity increases with age. The MDS provides values for motor ages (averages of test results that are expressed in months) and for motor quotients (motor age in each test, divided by chronological age, and multiplied by 100). The results for motor quotients refer to specific ranges, which classify respective levels of motor development, and which range from "very low" (equal to or below 69 points) to "very high" (equal to or up to 130 points). Positive ages or negative ages are determined by the difference between chronological age and general motor age (Rosa Neto, 2002). All tests were applied during single 40-min sessions.

Statistics were calculated using STATA, version 11.0 (Stata Corporation, College Station, TX, USA), and the level of statistical significance was $p < 0.05$. The Shapiro–Wilks test was used to investigate the framing of numerical variables in a Gaussian distribution. From the results of this test, we found that not all of the variables had numerical parametric distribution. Thus, average values and confidence intervals of 95% (CI 95%) were presented as descriptive statistics.

Subsequently, the Student *t*-test for independent data and the Mann–Whitney *U*-test established comparisons between the mean and median, respectively, for both groups.

3. Results

The results showed that the general motor quotients in all areas studied were lower in the individuals with ADHD than in the individuals in the control group, although in most cases they represent normal values, according to the MDS (Rosa Neto, 2002): Fifty-three percent of the patients with ADHD were classified as "normal medium", followed by 6% in the classification "normal high", 29% in "normal low", 9% in "very low", and 3% in "lower". In the control group, 78% of the children were classified as "normal medium", 13% as "normal low", and 9% as "normal high". None of subjects in this group were considered "lower" or "very low".

With regard to positive or negative ages, the results showed that most children with ADHD (88.3%) achieved negative ages, with an average of – 12.8 months. In the typically developing children, the average negative age was – 3.9 months and occurred in 53.1% of the sample.

The mean values of the motor quotients, according to the MDS, are illustrated in Table 1. The average score on the general motor quotient (89.3%) determined the categorization of motor development for the children with ADHD, combined subtype, as "normal low".

Table 2 illustrates the distribution of children, in percentages, and the classification of motor quotients for each motor skill. Of the scores that reflect "prejudice" ("lower" and "very low"), the percentages for children with ADHD were higher than for individuals without the disorder in all tests, except temporal organization.

Statistically significant differences between groups were noted in the majority of analyses, except for chronological age, motor age of fine motricity and motor age, and motor quotient of temporal organization, as shown in Table 3.

4. Discussion and conclusion

The motor profile outlined in this study showed that boys with ADHD, combined type, present difficulty in motor performance when compared to children without the disorder, as was described by other researchers (Fliers et al., 2009; Vidarte, Ezquerro, & Giraldez, 2009). The MDS allowed us to study various motor skills, and indicated that there were significant differences between groups.

Significant differences in motor skills, which resulted in below-normal motor development ("lower" and "very low"), were observed in 12% of the patients. However, the classification "normal low" determined negative ages, and thus reveals difficulties in the performance of some skills, indicating that 41% of the children with ADHD showed motor abnormalities.

Table 1
Classification of motor development and score.

	ADHD group		Control group	
	Score[a]	Classification	Score[a]	Classification
General motor quotient	89.3	Normal low	99	Normal medium
Fine motricity	94.4	Normal medium	104.1	Normal medium
Global motricity	97.9	Normal medium	107	Normal medium
Balance	93.1	Normal medium	102.7	Normal medium
Body schema	72.7	Low	83.2	Normal low
Spatial organization	78.7	Low	98	Normal medium
Temporal organization	101	Normal medium	100.7	Normal medium

[a] Mean of score in absolute values.

Table 2
Distribution in percentage of motor skills.

	Fine motricity		Global motricity		Balance		Body schema		Spatial organization		Temporal organization	
	ADHD	Control	ADHD	Control	ADHD	Control	ADHD	Control	ADHD	Control	ADHD	Control
Very low	2.9	0	2.9	0	8.8	0	41.1	28.1	11.7	9.3	11.7	6.2
Low	2.9	5.8	5.8	0	5.8	3.1	29.4	21.8	38.2	9.3	5.8	21.8
Normal low	26.4	15.6	17.6	12.5	26.4	12.5	20.5	18.7	14.7	18.7	8.8	6.2
Normal medium	58.8	43.7	50	34.3	44.1	46.8	5.8	15.6	26.4	34.3	35.2	26.4
Normal high	2.9	18.7	14.7	40.6	5.8	34.3	0	12.5	8.8	18.7	14.7	14.7
High	5.8	6.2	8.8	9.3	8.8	0	2.9	3.1	0	3.1	17.6	11.7
Very high	0	9.3	0	3.1	0	3.1	0	0	0	6.2	5.8	8.8

Values in %.

Table 3
Comparison between groups.

	ADHD group			Control group			p
	Mean	SD	CI 95%	Mean	SD	CI 95%	
General motor age	97	14	92.04–101.95	106.6	12	102.26–111.11	0.004*
Chronological age	108.7	13.1	104.13–113.27	107.2	10.6	103.45–111.10	0.137
General motor quotient	89.3	11	85.41–93.22	99	8.8	95.92–102.26	<0.001*
Motor ages							
Fine motricity	104.1	19	97.58–110.65	111.1	19	104.21–118.15	0.136
Global motricity	106.4	19	99.94–112.87	115.6	16	109.81–121.56	0.05*
Balance	101.2	20	94.30–108.28	110.6	14	105.62–115.62	0.032*
Body schema	78.7	16	73.04–84.36	89.2	20	81.96–96.53	0.021*
Spatial organization	85.7	26	76.77–94.75	104.2	20	96.92–111.57	0.002*
Temporal organization	108.7	22	100.85–116.55	108.7	25	99.69–117.80	0.875
Motor quotients							
Fine motricity	94.4	12.5	90.07–98.80	104.1	16.5	98.25–110.12	0.009*
Global motricity	97.9	14.4	92.91–102.97	107	12.6	102.56–111.62	0.008*
Balance	93.1	15.8	87.63–98.66	102.7	12.6	98.24–107.31	0.008*
Body schema	72.7	15.7	67.32–78.26	83.2	19	76.36–90.07	0.05*
Spatial organization	78.7	21.5	71.23–86.23	98	19.80	90.92–105.19	<0.001*
Temporal organization	101	23	92.97–109.02	100.7	23.3	92.35–109.14	0.9651

Mean: chronological age and motor ages in months, motor quotients in absolute values; SD: standard deviation, CI 95%: confidence interval 95%.
* $p \leq 0.05$.

This percentage falls within the range (30–50%) of incidence of motor abnormalities as described in clinical and epidemiological studies (Fliers et al., 2009; Pitcher et al., 2003).

This variation of motor development – from low to high and within the normal range – is expected, since the evolution of a child does not occur in a continuous manner, but, rather, in qualitative leaps that are followed by periods of maturation. However, the negative average age of those in the case group was particularly low (12.8 months), revealing the immaturity of some aspects of motor development.

This motor immaturity may be related to brain maturation delay, observed in Shaw et al.'s (2007) study: the average age at which individuals in this ADHD group reached the peak of cortical thickness was 10.5 years. This was significantly later than the average age (7.5 years) for the study's typically developing control children. The delay was most prominent in prefrontal regions that are linked to the ability to inhibit unwanted thoughts and responses, to the executive control of attention, to evaluation of rewards of action, to working memory, and to motor control necessary and appropriate for an expected action.

The cortical maturation delay in the prefrontal areas demonstrated by Shaw et al. (2007) may partially explain the delay in motor development observed in this study. Several studies have found significant volumetric reductions in the prefrontal cortex in patients with ADHD (Berquin et al., 1998; Valera et al., 2007). However, many motor skills are linked to other frontal areas, such as the pre-motor cortex and motor cortex, which are associated with capacity to perform related movements and basic motor acts and sequential functional assessments, such as those in the MDS (throw or catch a ball, jumping, etc.).

Although 53% of the children with ADHD in this study were classified as having "normal medium" motor development, the mean ratios of general motor quotients determined that their motor development was "normal low". This can be explained by the higher frequency of low scores in this group. We concur with Vidarte et al. (2009) that the motor profile of children both with and without ADHD can fall within the normal range, but that those with the disorder have lower scores and their levels of performance in each skill are poorer than those for their typically developing peers.

Currently, there is no consensus between researchers in how to best determine types of motor impairment in children with ADHD. This seems to be a plausible cause for discrepancies in assessment methods and within populations. Some studies have found strong associations between ADHD and problems with fine motor skills, while others have revealed a stronger relationship between the disorder and changes in gross motricity (Fliers et al., 2009; Pitcher et al., 2003; Visser, 2003). Pitcher et al. (2003) reported that the degree of movement difficulty differed between children with ADHD and typically developing children. We observed that, in the tests employed for evaluations as well as for the skills that are assessed, population samples often are associated with comorbidities and variations in gender, which could lead to differences in findings. Therefore, we opted for a carefully selected, homogeneous group of cases.

In the current study, with regard to fine motricity, motor ages were not statistically significant between groups (Table 3). That is, the scores on each test, as expressed in months, were not different. However, the motor quotients for this skill revealed statistically significant differences, indicating that when motor age was linked to chronological age, the case group performed with lower efficacy than the control group.

The impairment of fine and global motricity can be explained by neurological changes in cortical regions and their pathways, commonly found in ADHD. In the prefrontal cortex, orbital disorders are associated with social disinhibition and impulsive behavior; involvement of the dorsolateral cortex causes deficits in organization, working memory, and in planning and attention (Berquin et al., 1998; Valera et al., 2007). Many studies have shown a smaller cerebellar volume in ADHD patients as compared with controls, and others have shown decreased activity of the cerebellum, especially in the vermis (Berquin et al., 1998; Valera et al., 2007). Thus, the involvement of the cerebellum and associated circuitry may help us understand balance changes observed in children with ADHD. For example, problems related to planning, execution, and adjustment of movement could lead to deficits in balance, global and complex coordination, and potentially could cause interference related to school learning and daily activities. Bolfer et al. (2010) verified a slower reaction time in a computerized test for children with ADHD as compared to normal controls. This may be related to problems with an attentional system that cannot maintain the adequate capacity of perceptual input processes and/or motor output processes to respond consistently during continuous or repetitive activity.

The development of motor skills, including balance, may be important for self-esteem and to fine motor abilities that are essential to many activities of daily living, such as dressing and writing (Fliers et al., 2009; Visser, 2003). Motor tests are based on daily activities, and require sustained attention and impulse control. Since children with ADHD are more likely to experience difficulties with their daily activities, clinicians should be aware of the association between attention deficits, impulse control, level of activity, and different motor areas. These difficulties can be reflected in a child's refusal to explore new skills, and resistance to different activities in his or her daily routine as a means of protecting him- or herself from frustration, especially during collective events.

Since ADHD is a biopsychosocial disorder, its impact on quality of life in children with ADHD may occur independently of motor involvement. However, improvement in motor performance can help children develop skills and act on their feelings, thus enhancing their self-esteem (Goulardins, 2010).

The tasks used to assess body schema seem to imply different executive functions, which are controlled by neurological structures that are affected by ADHD. This, in turn, might explain why these participants have difficulties in performing the tests. The children with ADHD performed below the normal range, which was confirmed by statistical significance between the groups for motor age. However, we are unable to explain why the control group performed poorly on this task.

In the spatial organization task, we observed statistically significant differences in motor age and motor quotients, as did Vidarte et al.'s (2009) investigation. The development of this ability allows a child to exercise the processes of localization, orientation, visual-spatial recognition, and perception of distance, area, volume and speed, and it is considered to be the basis for mathematical processes.

Temporal organization helps to provide the child with concepts of order, duration, frequency, and rhythm, which implies a process of perception and memory of succession, processing, storage and re-memorization: the basic linguistic concepts (Poeta & Rosa Neto, 2007; Rosa Neto, 2002). Although these concepts are typically modified by the involvement of executive functions, these changes did not appear to be significant in the current study.

The evaluation of temporal organization employs language skills, and involves the repetition of phrases and the reproduction and symbolization of spatial structures. It also examines participants' ability to memorize and reproduce rhythmic motor structures, their auditory perception, and their short-term memory. However, Rosa Neto (2002) observed that the appropriate times to perform such tasks were difficult to determine, and that what was important was that the participants performed the tasks in the correct sequences. Since the performance analysis in the current study was not qualitative, we suspect that these factors could have mitigated our evaluation of motor impairment, and that this may constitute a limitation of the study.

In conclusion, children with ADHD are monitored through a multidisciplinary approach that includes drug treatment, cognitive-behavioral therapies, psychotherapy, and speech therapy, among others, and also includes the family environment. This indicates that their proper care is comprehensive. By adding motor therapies to the mix, professionals who have been specifically trained for this purpose (i.e., physical therapists and physical educators, for example) can help further ensure the breadth of the approach. This acts positively on their physical, mental, and social well-being (Fliers et al., 2009; Goulardins, 2010).

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