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NEURO-MOTOR DEFICITS IN SIX- TO EIGHT-YEAR OLD LEARNERS WITH ADHD AND DAMP

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ABSTRACT

This study investigated the nature of coordination, visual-motor integration and neurological functioning in children diagnosed with ADHD and whether the likelihood of motor impairment will increase with the presence of co-occurring DCD (DAMP). Ninety-five learners (60 boys; 35 girls) with a mean age of 6.9 years participated in the study. Four groups were compared: An ADHD only group (n=42); a group of typically developing children (n=18); a medicated group (n=14); and a DAMP group (n=21). The MABC-2, QNST-2 and the VMI-4 were used to assess the groups. Descriptive statistics (StatSoft, 2012), two-way frequency tables and an ANOVA were used to analyse the results. ADHD learners using medication had significantly poorer fine motor skills (p<0.05) than those with only ADHD or typical children. ADHD children using medication and DAMP learners displayed comparable fine motor skills and hand control, although both groups had more impaired fine motor skills than those with only ADHD or typical children. Overall coordination and selected sensory and perceptual impairments increased as a function of co-occurring DCD, indicating that motor coordination does account for overall motor coordination and perceptual and sensory deficits seen in ADHD. These results further confirm a link between ADHD and fine motor problems.

Key words: ADHD; DAMP; DCD; Neuro-motor control; Fine motor skills; Visual-motor integration.

INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is increasingly described as an everyday phenomenon in society. The American Psychiatric Association (DSM-5, APA, 2013) defines ADHD as a neuro-chemical imbalance in certain areas of the brain, with a strong genetic link. ADHD refers to a disorder that is accompanied by minimal brain dysfunction that includes symptoms like attention deficits, impulsivity and motor over-activity (Cantwell & Barker, 1991; Bester, 2006). According to the APA (2013), 3-7% of all children are affected by ADHD with a boy-girl-ratio of between 2:1 and 9:1 (Sherrill, 2004; Mahone *et al*., 2009; APA, 2013).

Poor motor coordination is reported among children with ADHD (Piek *et al*., 1999; Sergeant *et al*., 2006). Clinical and empirical studies report that 30-50% of children diagnosed with ADHD experience problems with motor coordination. This percentage varies according to the type of motor assessment applied (Gillberg, 1998; Kadesjo & Gillberg, 1998; Geuze *et al*., 2001). Fliers *et al*. (2007) report that motor-coordination problems are present in one-third of all ADHD-children and that it affects both boys and girls. In an overview article, Harvey and Reid (2003) indicate that children with ADHD have lower physical fitness levels, poorer fine motor skills and also experience problems with gross motor skills.

Most literature, however, indicate a stronger relationship between ADHD and fine motor problems (Szatmari & Taylor, 1984; Harvey & Reid, 2003), although certain studies also report a relationship between ADHD and gross motor problems (Harvey & Reid, 2003; Pitcher *et al*., 2003; Visser, 2003; Tseng *et al*., 2004). Piek *et al*. (1999), claim that the motor impairment of children with ADHD could rather be the result of attention deficiency caused by ADHD, as a secondary result of the disorder rather than a primary symptom. However, Miyahara *et al*. (2006) differ from the above findings and report that fine motor deficiencies are not associated with attention. Kooistra *et al*. (2005) also report no differences between motor impairment of ADHD children and typical children and that motor impairment in ADHD increases as a function of co-occurring disorders, such as reading disability and opposition defiant disorder.

Zang *et al*. (2002) further report an 81.6% overlap of sensory integration dysfunction with ADHD. Ayers (1972) indicates that a lack of inhibition, together with a combination of lack of motor coordination, poor motor planning, varying degrees of perceptual-motor coordination and balance shortcomings are all indicative of sensory integration dysfunction. Furthermore, children with ADHD obtained lower marks in the Sensory Integration Praxis Test (SIPT) for spatial visualisation (mental manipulation of objects in space), static and dynamic balance, copy-design (duplication of a design on a spotted card) and post-rotary nystagmus. These results indicate an inhibition in the vestibular and somato-sensory systems (Ayers, 1972). In addition, the quality of the execution of movement skill patterns among children with ADHD using stimulant medication is described as below average. In this regard, Harvey and Reid (2003) report that locomotor and object control skills of these children were under the 35th percentile when compared with age-related norms.

Researchers report co-morbidity between Developmental Coordination Disorders (DCD), learning-related problems and Attention Deficit Hyperactivity Syndrome (ADHD) (Geuze & Börger, 1993; Schoemaker *et al*., 1994). Scandinavian countries refer to a combination of ADHD and motor-coordination problems (DCD) as “Deficits of Attention and Motor Perception (DAMP)”. DAMP is defined as a combination of attention deficit syndrome (ADD), with or without the impediment of hyperactivity or impulsivity, with hampering delays in at least one of the following areas: bilateral motor skills; fine motor skills; perception; and speech and language, in the absence of visible mental retardation and cerebral palsy or another major neurological deviation (Harvey & Reid, 2003).

It appears that overlapping conditions like DAMP (ADHD and DCD) have a greater prevalence of motor problems than when a child displays only ADHD symptoms (Gillberg, 2003; Gibbs *et al*., 2007). In this regard, Harvey and Reid (2003) recommend that future research should describe motor skills of ADHD children from which those who warrant a specific designation of DCD are eliminated from the participant pool, thus not also have DCD to warrant a DAMP classification to determine whether ADHD predicts motor impairment.

RESEARCH PROBLEM

The aim of this study was to examine the nature of coordination-related neuro-motor impairment, as well as visual-motor integration problems among a selected group of 6 to 8 year old children who have been diagnosed with ADHD and DAMP. This research was based on the assumption that children with ADHD in this age range will have neuro-motor impairments and that the nature and extent of the neuro-motor impairments will increase in the presence of co-occurring DCD (DAMP).

METHODOLOGY

Research group

Ethical permission was granted by the NWU ethics committee (nr.06M04) to conduct the study. The headmasters of the 3 different schools selected for the study were asked for permission to conduct the research at the respective schools. A cross-sectional, convenience sample, based on availability was used and Grade 1 and Grade 2 learners from the 3 different schools who were classified with and without ADHD in Brakpan, South Africa, formed the research group. Three quintile 4 schools, which included learners with similar socio-economic backgrounds and diversity, participated in the study. The teachers of the Grade 1 and Grade 2 learners in the selected schools were asked to identify children in their classes, who displayed disruptive behaviour, which could be indicative of ADHD. The teachers and the parents then completed the 18-item ADHD *Disruptive Behaviour Scale* (DBS) (Bester, 2006), for ADHD and both scores were used to identify the subjects for the study.

The research group consisted of 95 learners (60 boys; 35 girls) with a mean age of 6.9 years. The participants were divided into 4 groups for the purpose of comparison. *Group 1* consisted of learners (n=42) that had been diagnosed by means of the DBS with ADHD. *Group 2* consisted of ADHD-learners (n=14) who were diagnosed with ADHD and who were on medication (Ritalin or Concerta), for ADHD. Information about the use of medication for ADHD was obtained by means of a medical history questionnaire that the parents had to complete additionally when they provided consent for the study. *Group 3* included learners (n=18), who did not show symptoms of ADHD. These learners were selected from the classes involved in the study by their teachers who identified them as learners who did not display concentration problems and were probably not ADHD candidates. This was verified by their DBS scores. *Group 4* consisted of learners (n=21), who scored high enough on the *Disruptive Behaviour Scale* and the MABC-2 to be included as a group with both ADHD and DCD (DAMP classification), and who did not use any form of medication for ADHD, as verified from the medical history provided by their parents.

Learners whose parents granted permission for them to participate in the study were thoroughly evaluated with the QNST-2, VMI-4 and MABC-2. Baseline measurements were taken during school hours in the second school term. It is important to note that diagnose, in the context of this study, only meant that the learners were not on medication, were identified according to the DBS as ADHD candidates, and were not necessarily formally diagnosed by a medical practitioner.

Measuring instruments

Movement Assessment Battery for Learners" (MABC)-2

This measuring instrument was developed by Henderson *et al*. (2007) for children in the age range of 4 to 12 years and was used to determine their motor development status. Good validity and reliability was reported for the MABC in the MABC manual (Henderson *et al*., 2007:132-139), and by other researchers (Leemrijse *et al*., 1999). The MABC-2 measures fine motor skills (FMS) (3 test items), aiming and catching or ball skills (BS) (2 test items), as well as static and dynamic balancing skills (BLS), which can be calculated separately, as well as combining them for a DCD-total score. The test is norm-based and classifies children who fall on or below the 5th percentile with DCD of a serious nature, which requires remedial help. When a child is classified between the 5th and 15th percentile, he/she is considered a DCD risk and someone who possibly requires remediation.

According to the "traffic light system" of the MABC-2, a subject is placed in a red zone (a standard score of 56 or less and a percentile of $\leq$5%), a yellow zone (standard score of between 57 to 67 and a percentile of between 5% and 15%), or a green/normal zone (for any standard score above 67 and smaller than the 15th percentile). The red zone refers to an existing motor delay (DCD) and the yellow zone refers to a risk for the development of motor delays, while a percentile equal to and greater than 16 indicates normal motor functioning. A higher standard score in the MABC-total and the 3 subscales, thus, indicate better achievement in this test. The various test items of the MABC-2 were assessed by trained researchers with post-graduate qualification in Kinderkinetics.

Quick Neurological Screening Test 2 (QNST-2)

The QNST-2 (Mutti *et al*., 1998) is a criteria-based measuring instrument consisting of 15 sub-components that measure visual discrimination, visual perception, fine motor control, hand-eye coordination, muscle tone, motor planning and sequence, spatial orientation and bilateral coordination. The QNST-2 can also be used to verify attention span, distraction, impulsivity, non-verbal concept forming, concept-forming, including perceptual organisation, spatial visualisation and orientation, as well as visual-motor integration. This measuring instrument is suitable for use on persons from the age of 5 to adulthood (Mutti *et al*., 1998). The total score for the QNST-2 is obtained by adding the scores of the 15 subtests. A high score (a total raw count above 50), indicates that the child will probably experience learning problems in the mainstream classroom, while a moderate score (a total 26 to 50) usually indicates moderate maturation delays or moderate neurological impairment. A normal score (25 and less), indicates that the child does not have problems that indicate specific learning deficits.

Developmental Test of Visual-Motor Integration (VMI)-4

The VMI-4 (Beery & Buktenica, 1997) is a developmental sequence of geometric forms that have to be copied with pencil on paper. The purpose of the VMI-4 is to do an early screening to identify children who may require special help for the purpose of obtaining the necessary services, testing the efficiency of educational and other interventions and promoting research. The complete 27-item VMI-4 can be applied individually or in a group within 10 to 15 minutes and is suitable for use from pre-schoolers up to adulthood. An 18-item version is available for 3 to 7 years of age. The VMI-4 allocation of points is based on a "point" or "no point" criteria. The VMI-4 version also consists of 2 sub-tests, namely motor coordination and visual perception. The criteria for the VMI-4 allocation of points are as follows: points are allocated according to the number of test divisions the child had completed correctly. The assignment is stopped when a child has executed 3 consecutive test items incorrectly and/or upon completion of a section. After the allocation of points, the standard points are used to place the child in 1 of the 5 groups, from well below average to well above average: 40 to 47 are well below average; 68 to 82 are below average; 83 to 117 is average; 118 to 132 are above average; and 133 to 160 are well above average.

***Disruptive Behaviour Scale* (DBS)**

The *Disruptive Behaviour Scale* compiled by Bester (2006) is used to indicate whether a child has attention deficit or not. The 18-item questionnaire is similar to the "Modified Conner's Abbreviated Teacher Scale" (Lowenberg & Lucas, 1999), and the abridged version of the Australian Disruptive Behaviour Scale (Piek *et al*., 1999), that is used to identify ADHD. Teachers and parents completed separate questionnaires for each child where they had to indicate which statement currently or during the previous 6 months was most applicable to the child by ticking "never" or "very often" in the different columns.

Items 1 to 9 (A), of the questionnaire focused on ADD (attention deficiency) symptoms and items 10 to 18 (B), on hyperactivity-impulsivity symptoms, whilst 1 to 18 focused on the ADHD (combination type). Allocation of points for the response was as follows: 0= never; 1= now and then; 2= sometimes; 3= regularly; 4= very often. The higher the total, the more characteristics of ADHD are present. There is also an additional column in which teachers and parents have to indicate whether the behaviour experienced is considered as problematic by ticking "Yes" or "No". When the total of A or B is above 24 and it occurs in 2 functional environments, for example, school and home, the child displays a high enough number of symptoms to be diagnosed with ADHD, for example 48 and more. However, more than 6 "Yes" answers have to be ticked in group A or B. The scoring of the responses and interpretation of the results of the "Disruptive Behaviour Scale" was completed by the researcher.

Statistical analysis

The Statistica Release 10 (StatSoft, 2012) computer programme package was used to process the data. Firstly, data was analysed for descriptive purposes by means of mean (M) and standard deviations (SD) (StatSoft, 2012). An analysis of variance (ANOVA) was computed with a Tukey post-hoc analysis to further analyse differences between the groups. A p-value of ≤ 0.05 was accepted as statistically significant.

RESULTS

Table 1 provides the descriptive characteristics relating to gender, age and the number of participants in each of the 4 groups. The groups with ADHD (groups 1 to 3) included more boys than girls with a 1:3 ratio of girls to boys in both the ADHD (Group 1) and the medicated group (Group 2), whilst the DAMP-group (Group 3), had a ratio of 1:2. The group without ADHD was comprised of more girls than boys.

TABLE 1. **GROUP CHARACTERISTICS FOR GENDER AND AGE**

Variables	Total group	ADHD (G1)		Medicated (G2)		DAMP (G3)		Without ADHD (G4)	
	N	n	%	n	%	n	%	n	%
Girls	35	13	37.1	3	8.6	9	25.7	10	28.6
Boys	60	29	48.3	11	18.3	12	20.0	8	13.3
Total group	95	42	44.2	14	14.7	21	22.1	18	18.9
Mean age yrs	6.99	7.00		7.00		6.86		7.10	
SD age	0.64	0.66		0.55		0.73		0.58	

SD= Standard Deviation G= Group

In the first comparison where learners with ADHD were compared to those without ADHD, the ADHD group was not divided into separate ADHD (n=42) and DAMP (n=30) groups, but was analysed as one ADHD group (n=62). Table 2 displays the results of the group with ADHD (n=62), the medicated ADHD group (n=14) and the group without ADHD (n=18), regarding standard scores and totals obtained in the MABC-2, QNST-2 and VMI-4.

Significant differences ($p<0.05$) were found between the standard scores of the groups for fine motor skills, where the medicated group obtained a significantly poorer mean score compared to the other 2 groups. No significant differences were found in ball or balancing skills or in the MABC total of the different groups. The mean values for visual-motor integration (VMI), visual perception (VP) and motor control (MC) subtests and the QNST-2 total also reflected no significant differences between the groups. The *Palm Form-Recognition* subtest of the QNST-2, however, reflected that the medicated group (4.57±2.31) obtained a significantly poorer mean score than the ADHD group (3.55±2.24) and the group with ADHD (2.94±2.20). Stimulation of the *Hand and cheek* also reflected significant differences ($p=0.047$) between learners with ADHD (1.33±1.67) and those without ADHD (0.50±1.15), where learners without ADHD did significantly better. No significant differences were found in the other subscales of the QNST-2. In general, a trend was observed that the learners without ADHD displayed better mean scores than the medicated group and the group with ADHD in the test variables.

Table 3 displays the results of a similar comparison as reported in Table 2, but with the ADHD group divided into an ADHD and DAMP group. The *MABC-2-percentile* ranking of the DAMP-group (1.30±0.73) was significantly lower than that of the other groups ($p<0.05$). The medicated group obtained the lowest value for fine motor skills, while both the medicated and DAMP group displayed significantly poorer fine motor skills compared to the ADHD and without ADHD groups. The DAMP group obtained the lowest mean MABC total (52.35±16.18), followed by the medicated group (54.15±16.12), compared to the means values obtained in the without ADHD (59.10±18.8) and ADHD group (60.18±10.89), although these differences between the groups were not significant. From a clinical perspective, both the DAMP and medicated groups were categorised below the 5th percentile and in the red zone, which indicates evidence of severe DCD in these groups.

TABLE 2. **GROUP DIFFERENCES: WITHIN MABC-2, VMI-4 & QNST-2**

Variables	**ADHD (alone) (G1)** (n=42) M±SD	**Medicated (G2)** (n=14) M±SD	**Without ADHD (G3)** (n=18) M±SD
Fine motor skills	6.22±2.99[2]	4.69±1.97[1,3]	7.50±3.25[2]
Aiming & catching skill	7.98±3.08	9.00±2.79	7.63±2.94
Balance skills	6.76±2.24	5.92±2.93	7.69±2.62
MABC-Total	58.08±13.31	54.15±16.12	59.10±18.8
MABC-SS	5.94±2.38	5.38±2.90	6.63±1.96
DCD-Percentile rank	2.19±0.85	2.38±0.87	2.63±0.62
Visual-motor integr. SS	89.85±15.35	90.38±13.74	87.38±25.78
Visual perception SS	87.42±20.10	80.31±27.23	96.01±19.4
Motor coordination SS	83.29±16.12	84.23±18.81	92.20±12.19
QNST-2-Total	45.14±11.50	38.46±12.14	41.10±11.39
QNST-2-Category	2.34±0.81	2.15±0.80	2.56±0.73
Hand skill	1.11±0.62	1.00±0.55	0.83±0.70
Figure recognition	2.46±1.14	2.28±0.82	2.16±0.85
Palm form-recognition	3.55±2.24[2,3]	4.57±2.31[1,3]	2.94±2.20[2]
Eye function	4.44±3.22	3.85±3.67	5.11±3.61
Sound patterns	7.57±3.68	6.50±3.79	8.22±5.00
Finger to nose	3.53±1.77	3.07±1.38	3.44±1.09
Thumb-finger-circles	3.42±1.73	2.71±1.20	3.38±2.09
Stimulation, hand & cheek	1.33±1.67[3]	0.57±0.51	0.50±1.15[1]
Repetitive hand movements	3.00±2.63	2.21±1.47	2.16±2.95
Arm-and-leg extension	5.14±2.43	3.64±2.92	3.83±3.05
Tandem walk	3.22±1.94	3.28±2.33	2.88±1.99
One-legged standing	2.01±1.25	2.33±2.00	2.11±1.23
Skipping	0.31±0.96	0.35±0.84	0.33±0.84
Left-right discrimination	2.46±0.85	2.07±1.14	2.27±0.75
Behaviour	1.53±1.01	1.92±1.07	1.22±1.06

M= Mean SD= Standard Deviation p-value ≤ 0.05 SS= Standard score,
G= Group [1,2,3] = Significant differences between groups

A big variation was, however, evident from the standard deviations in all the groups which should be noted. No group differences were found between the mean scores obtained for the VMI and the visual perception subtest of the VMI, although the *motor coordination* subtest scores indicated significant group differences, where the DAMP group performed significantly poorer than the ADHD group (p=0.001) and the group without ADHD (p=0.005).

TABLE 3. **GROUP DIFFERENCES: MABC-2, QNST-2 AND VMI-4 IN DIFFERENT CATEGORIES OF ADHD AND DAMP**

Variable	**DAMP (G1)** n=30 M±SD	**ADHD (alone) (G2)** n=42 M±SD	**Without ADHD (G3)** n=18 M±SD	**Medicated (G4)** n=14 M±SD
Fine motor skills	4.95±2.68[2,3]	6.81±2.97[1]	7.50±3.25[1,4]	4.69±1.97[1,3]
Aiming & catching sk.	7.50±3.58	8.21±2.82	7.63±2.94	9.00±2.79
Balance skills	6.40±2.74	6.93±1.98	7.69±2.62	5.92±2.93
MABC-Total	52.35±16.18	60.81±10.89	59.10±18.8	54.15±16.12
MABC-SS	5.00±2.85	6.38±2.01	6.63±1.96	5.38±2.90
MABC-percentile	1.30±0.73[2,3,4]	2.61±0.49[1]	2.63±0.62[1]	2.38±0.87[1]
VMI SS	87.95±16.20	90.76±15.04	87.38±25.78	90.38±13.74
Visual Perception SS	82.15±23.95	89.93±17.77	96.01±19.40	80.31±27.23
Motor Coordin. SS	71.15±17.99[2,3]	89.07±11.39[1]	92.20±12.09[1]	84.23±18.81
QNST-2-Total	48.70±11.93	43.42±11.03	41.13±11.39	38.46±12.14
QNST-2-category	2.05±0.89	2.48±0.74	2.56±0.73	2.15±0.80
Hand skill	1.15±0.63	0.96±2.22	0.83±0.70	1.00±0.55
Figure recognition	2.61±1.22	2.22±0.91	2.16±0.85	2.28±0.82[1]
Palm form recognition	3.81±1.97[4]	3.43±2.45	2.94±2.20[1]	4.57±2.31[1,3]
Eye function	4.73±3.26	4.31±3.41	5.11±3.61	3.85±3.67
Sound patterns	7.57±3.56[4]	7.51±4.24	8.22±5.00	6.50±3.79[1]
Finger-to-nose	3.57±1.62	3.36±1.61	3.44±1.09	3.07±1.38
Thumb-finger-circles	3.39±1.85	3.26±1.68	3.38±2.09	2.71'±1.20
Hand/cheek stimulation	1.34±1.54	0.87±1.46[3,4]	0.50±1.15[2,4]	0.57±0.51
Repetitive hand movem.	2.94±2.45	2.57±2.65	2.16±2.95	2.21±1.47
Arm-and-leg extension	5.28±2.64[4]	4.26±2.65	3.83±3.05	3.64±2.92[1]
Tandem walk	3.23±2.01	3.12±2.01	2.88±1.99	3.28±2.33
One-legged standing	2.15±1.12	1.94±1.31	2.11±1.23	2.33±2.00
Skipping	0.31±0.93	0.33±0.91	0.33±0.84	0.35±0.84
L/R-discrimination	2.42±0.82	2.33±0.93	2.27±0.75	2.07±1.14
Behaviour	1.65±1.02	1.45±1.05	1.22±1.06	1.92±1.07

SD= Standard Deviation M= Mean p-value ≤ 0.05 SS= Standard score,
G= group [1,2,3,4] = Significant differences between groups VMI = visual-motor integration

From a clinical perspective, the scores obtained by the DAMP and medicated group for visual perception indicated below average performance, while the DAMP group additionally showed below average performance in their motor coordination or hand control skills which was significantly poorer compared to the other groups.

The DAMP group (48.70±11.93) also obtained higher and thus poorer values in the QNST-2 total, compared to the other groups, although the differences between the groups were not statistically significant. The highest variation in mean scores was, however, evident from the standard deviations in the DAMP and medicated groups which could have influenced the results. The DAMP group obtained significantly poorer scores than the medicated group in the *Palm Form Recognition*, *Arm-and-leg extension* and in the *Sound patterns* subscales. The stimulation of the *Hand-and-cheek* subscale also yielded significant differences between groups, where the ADHD and typical children obtained significantly better mean scores than the medicated group (M=0.57). In general, a trend was observed that the children with ADHD alone and typical children displayed better scores compared to the medicated and DAMP groups in the QNST test variables·

DISCUSSION

The purpose of this study was to examine the nature of coordination-related neuro-motor deficiencies and visual motor integration problems in a selected group of 6 to 8 year old children with ADHD, and to establish whether impairment increased with co-occurring coordination problems (DAMP). The results confirmed that children with DAMP had poorer fine motor coordination than those in their peer group who were classified with ADHD (alone), or as typical children. All three measuring instruments that were used in the study included assessments of fine motor skills and all these confirmed inferior fine motor skills in children with DAMP. Significant differences were found in the MABC (fine motor skills) and VMI (hand control as assessed by the motor coordination subtest), with a trend in the QNST where the DAMP group obtained the poorest score of the different groups for hand skills (Table 3). Typical children displayed the best fine motor skills of the different groups, which was, however, not significantly superior to that of ADHD (alone) children (Table 2). When the ADHD groups were separated (Table 3), the differences became significant between the DAMP and the ADHD (alone) groups, confirming that co-occurring coordination problems contribute to impairment of fine motor skills (FMS).

Furthermore, learners with DAMP had significantly poorer FMS than the group with ADHD alone. The group on medication also differed significantly from the ADHD (alone) group and the control group of typical children regarding their fine motor skills, although they displayed similar poor fine motor skills as the DAMP group. This leads to the conclusion that the medicated group probably included children suffering from ADHD of a more serious nature who are for this reason, already using medication for the syndrome. The medicated group could also not be separated further if DCD were identified within this group, which could also have contributed to the poorer values found in this group compared to the ADHD (alone) group.

These results agree with the findings of Piek *et al*. (1999), Harvey and Reid (2003) and Pitcher *et al*. (2003), who indicated that children with ADHD experience FMS problems. This confirms that when children with ADHD also experience problems with coordination, to such an extent that they can be classified with DAMP, their fine motor skills will be more impaired. Kooistra *et al*. (2005) reported supporting evidence that motor impairment in ADHD increased as a function of co-occurring disorders, and that the presence of reading disorders, rather than ADHD, predicted motor impairment.

The results of the study of Pitcher *et al*. (2003) on 7 to 12 year old boys using the MABC-2 and the "Conner's Parent Rating Scale-Revised", indicated in that ADHD learners experienced motor coordination problems similar to those of learners with DCD (developmental coordination disorder), especially among ADHD learners with predominant attention problems, and the combined sub-type who experienced problems with FMS. According to these researchers these problems cannot be ascribed to attention deficit, but rather to problems with motor skills (DCD co-occurring with ADHD). Contradictory to this, Polderman *et al*. (2011) report a weak association between ADHD and motor control accuracy, and no association with motor control stability as tested by means of pursuit tracking.

The results of the current study confirmed inferior fine motor skills among ADHD children, irrespective of whether they had DCD or not, but it was also clear that fine motor impairment increased as a function of co-occurring DCD (DAMP classification). The MABC percentile ranking of the DAMP group also indicated general overall poor coordination in this group. Along with the medicated ADHD group, both groups obtained a mean MABC total that placed them in the severe DCD zone which, from a clinical perspective, indicated that these children need remediation for their coordination problems. DAMP children also displayed additional perceptual and sensory problems as indicated by three subtests in the QNST (*Palm-form recognition, Arm-and-leg extension, Sound patterns*), which were not found in the medicated ADHD group ADHD (alone), or typical children. DAMP and the medicated ADHD learners furthermore displayed visual perception standard scores according to the VMI manual that categorised both groups in an under average category.

These results agree with literature that report that co-occurring conditions, such as DAMP (ADHD and DCD), contribute to increased motor impairment compared to when ADHD occur alone (Gillberg, 2003; Gibbs *et al*., 2007). These results also agree with the findings reporting negative impacts of DAMP on daily activities that require fine motor coordination, e.g. dressing, eating and academic achievement due to poor writing skills (Gibbs *et al*., 2007). Gillberg *et al*. (1983) also reported that learners with DAMP between the ages of 6 and 8 years, who had been evaluated in a neurological screening test, displayed significant lower values than a control group over a period of 10 years. Recent studies claim that DAMP is not attention related, but should rather be regarded as a motor delay problem (Miyahara *et al.*, 2006).

The QNST-2 total of the DAMP group was the poorest of all the groups compared, although no group differed significantly from one another. Although a trend was established that the DAMP group obtained the lowest scores in all the subtests of the QNST-2, no significant differences were found indicating that their performance was worse than the ADHD group and the without DCD group. Significant differences were, however, established between the DAMP and medicated groups in three subtests of the QNST-2, indicating worse perceptual and sensory functioning skills in the DAMP group compared to ADHD children using medication for the condition.

Kutcher (2002) describes the child with ADHD as one who neither starts to focus on a new task beforehand, nor is capable of focusing or paying attention to what is important at the moment. Relevant sensory stimuli are thus lost during the information processing phase, which is indicative of sensory integration dysfunction. The child with ADHD could as a result be sensory dull (Oaklander, 1994). By applying selective attention to a task, a child is able to ignore unimportant information and only focus on what is important. These may provide possible reasons why learners with ADHD had poorer sensory sensitivity than the group without ADHD during perception and sensory integration skills, since this group did not receive any medication.

Therefore, the findings of this study agree with literature findings that indicate that when learners with ADHD also experience motor coordination problems, fine motor skill deficits are more prevalent.

LIMITATIONS AND RECOMMENDATIONS

This study had limitations that need to be acknowledged. A relatively small group formed part of the study, which became even smaller when the group was divided into more specific groups. Only the children in the medicated group were diagnosed formally by a medical practitioner, while the 'diagnoses' made for the other children were based on the DBS scores that were obtained from parent and teacher assessments. The medicated group could furthermore, not be subdivided if DCD was diagnosed, because of the small number of participants in the group, and their results could subsequently be masked by this. The overall group was also analysed as an ADHD group, without taking into consideration the different subtypes of ADHD, such as predominant attention and hyperactive impulsivity types because of the small number of participants, which could also have influenced the results. Further research is, therefore, recommended where similar comparisons can be drawn by also taking the different sub-types of ADHD into account. Further studies are, furthermore, also recommended to confirm the results of this study.

CONCLUSIONS

The findings of this study confirmed that fine motor skills of children with ADHD, who are using medication, such as Ritalin and Concerta, and ADHD children with co-occurring DCD (DAMP), are impaired compared to children with ADHD, who are not using medication and typical children. Furthermore, impaired overall coordination and perceptual and sensory motor functioning in ADHD increased as a function of co-occurring coordination disorder, and the presence of DAMP, rather than ADHD, predicted perceptual and sensory motor impairments.

Neurological functioning as assessed by different testing protocols and visual motor integration skills did not appear to differ among children with or without ADHD symptoms.

Notwithstanding, tendencies of lower values and significant differences in *Palm form recognition, Arm-and-leg extension* and *Stimulation of the hand and cheek* and *Sound patterns* subscales were found in the DAMP group compared to the medicated group suggesting sensory shortcomings in tactile and perceptual skills, as well as in muscle tone. The performance of the medicated group in these neurological screening subtests was similar to the ADHD (alone) and typical children as no significant differences were found between these groups. This suggests a positive outcome of medication on perceptual and sensory functioning, and subsequently neurological functioning in general on the attention of these children.

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