African Journal for Physical, Health Education, Recreation and Dance (AJPHERD)
Vol. 17, No. 4 (December: 2) 2011, pp. 888-902.

The nature and scope of ocular muscle control deviations among 7 to 8 year-old children diagnosed with DCD

DANÉ COETZEE AND ANITA E. PIENAAR

School of Biokinetics, Recreation and Sport Science, North-West University Potchefstroom Campus, Private Bag X6001, Potchefstroom 2520, Republic of South Africa;E-mail: Dane.Coetzee@nwu.ac.za

(Received: ; Revision Accepted:)

Abstract

The purpose of the study was to determine, as ascertained by different ocular muscle controlled functions, what the nature and scope of these problems are among 7 to 8 year-old children diagnosed with DCD. Thirty-two children between the ages of 7 - 8 took part in the study. The Movement Assessment Battery for Children (MABC) was used to classify children into moderate and severe DCD categories (<15th and the 5th percentile) while the Sensory Input Systems Screening Test and QNST II were used to evaluate visual functions that are controlled by the six eye ocular muscles. Correlation matrices and a two-way variance table were used to determine the relationship between DCD and vision functions. The results confirmed significant correlations between DCD and ocular muscle control deviations. Relationships were found between all the ocular muscle controlled functions (fixation, visual pursuit, left and right eye, ocular alignment right eye) and the MABC-total, manual dexterity, ball skills and static and dynamic balance. Significant correlations, with small ($d \geq 0.2$) to moderate practical significance ($d \geq 0.5$) were found between the different MABC sub sections and the ocular muscle controlled functions. The results further indicated that in most cases where children have been diagnosed with severe DCD, they were classified in Class 3 (more than three symptoms indicating poor ocular muscle control). These percentages varied from 26.67% to 83.33%, with the highest percentage problems found during visual pursuit with the right eye. It can be concluded that DCD and the severity thereof and visual deviations are related, and that children experiencing such problems could possibly be hampered academically and motorically.

Keywords: Developmental coordination disorder (DCD), fixation, ocular motor control, visual pursuit, visual problems.

How to cite this article:
Coetzee, D. & Pienaar, A.E. (2011). The nature and scope of ocular muscle control deviations among 7 to 8 year-old children diagnosed with DCD. *African Journal for Physical, Health Education, Recreation and Dance,* 17 (4: 2), 888-902.

Introduction

Developmental Coordination Disorder (DCD) is a diagnosis that indicates limitations with motor clumsiness and the development of motor coordination. Children classified with DCD are characterised with normal intelligence, and no known neurological condition or physical disability is present (American Psychiatric Association, 2000). The occurrence of DCD worldwide in school aged children, between the ages of 5 and 11 years, has been reported by the American Psychiatric Association (APA, 2000) and other researchers (Hoare & Larkin, 1991; Wright & Sugden, 1996; APA, 2000) to be between 3% and 22%.

This condition appears to be a serious problem in children, of which the cause can be attributed to a number of reasons (Hoare & Larkin, 1991; Dussart, 1994; Missiuna, 1994; Sigmundsson, Ingvaldsen & Whiting, 1997; Piek & Dyck, 2004; Piek, Dyck, Niemand, Anderson, Hay, Smith, McCoy & Hallmayer, 2004; Peens, 2005; Pienaar, 2008). One cause for motor deficiencies which can also contribute to a DCD classification appears to be poor ocular muscle control (Geuze & Börger, 1993; Lefebvre & Reid, 1998). Problems linked with DCD are poor concentration during the performance of tasks, problems with reading, writing and fine motor skills (Geuze & Börger, 1993; Lefebvre & Reid 1998; Piek & Dyck, 2004; Peens, 2005), activities related to hand-eye and foot-eye coordination (Hoare & Larkin, 1991; Wright & Sugden, 1996), *attention-deficit hyperactivity disorder (ADHD)* (Farrar, Call & Maples, 2001; Borsting, Rouse, & Chu, 2005) *and learning related problems* (Kaplan, Wilson, Dewey & Crawford, 1998; Dewey, Kaplan, Crawford & Wilson, 2002; Jongmans, Smits-Engelsman & Schoemaker, 2003).

Vision is considered the primary source with which the brain perceives information from the environment (Cheatum & Hammond, 2000). If the sensory input systems, of which the visual system is one, functions ineffectively, the execution of motor skills could be affected negatively (Pienaar, 2008). The visual system and well-developed ocular muscles appear to play an important role in the development of balance, spatial orientation, body awareness, coordination (hand-eye, foot-eye, hand-foot-eye coordination) and reading and writing skills (Rösblad & Von Hofsten, 1994; Langaas, Mon-Williams, Wann, Pascal & Thompson, 1998; Bouchard & Tetreault, 2000; Cheatum & Hammond, 2000; Reimer, Smits-Engelsman & Siemonsma-Boom, 2000; Tolla, 2000; Schoemaker, Van Der Wees, Flapper, Verheij-Jansen, Scholten-Jaegers & Geuze, 2001). Various researchers further indicate that visual feedback, visual perception , visual pursuit, depth perception, figure background recognition and visual-motor integration are required to effectively plan and execute motor skills (Lord & Hulme, 1987; Willoughby & Polatajko, 1995; Fletcher-Flinn, Elmes & Stragnell, 1997; Mon-Williams, Wann & Pascal, 1999; Van Waelvelde, De Weerdt, De Cock & Smits-Engelsman, 2004). Winnick (2005) reports that visual perception is important in academic skills such as writing, drawing, reading, mathematical skills and fundamental movement skills such as running, kicking, throwing, catching and hitting an object. Poor ocular muscle control could also contribute to poor concentration and indirectly to poor self esteem (Aucamp, 2001; Pienaar, 2008). As a result, if there is any faulty input of information by way of the visual system, the reaction of the motor output to such information will also be faulty, which could lead to motor deficiencies (Pienaar, 2008). It therefore appears that academic problems and motor deficiencies can be the result of visual deviations.

The receptors of the visual system are the eyes (Cheatum & Hammond, 2000). Each eye has three pairs of ocular muscles, namely the rectus lateralis and medialis, rectus superior and inferior and the superior and inferior oblique. These muscles are attached to the top, bottom and on both sides of the sclera. When all six extra ocular muscles work in harmony, and move together, eye movement will be coordinated, resulting in a single image in the visual cortex (Cheatum & Hammond, 2000; Wilson & Falkel, 2004; Pienaar, 2008). These muscles are responsible for the correct movement of the eye, which helps to focus/fixate on objects, to track an object and ensure cohesive movement (Cheatum & Hammond, 2000; Wilson & Falkel, 2004). Ocular muscles can function together or separately to produce various eye movements (Wilson & Falkel, 2004). When the eyes converge (both eyes move towards each other, but still maintain a single image), both the medial rectus muscles must contract simultaneously. When these ocular muscles do not function properly, the eyes will tire rapidly, which will cause visual deficiencies (for example, the accuracy of the eye movements and the speed with which the eye moves will decrease). This can contribute to both eyes jumping around in an attempt to find the object again or an unclear/double image of the object can be experienced (Wilson & Falkel, 2004; Pienaar, 2008). Ocular muscles must be coordinated to be able to hold the convergence-divergence position to ensure that children can focus on an object with both eyes (Cheatum & Hammond, 2000; Pienaar, 2008). It therefore appears that good ocular muscle control plays an important role in the proper functioning of the visual system, and hence, in the effective execution of academic skills (Langaas *et al.*, 1998).

Cheatum and Hammond (2000) reported that approximately 25.00% of school-going children (whose academic skills varied from no problems to learning problems) experienced different ocular muscle control problems, while research by Pienaar (1993) on children with neuro-motor deficiencies, indicated that 12.55% also exhibited ocular muscle control problems. Research done by Coetzee and Pienaar (2010) on children diagnosed with DCD indicated that an average of 85.94% of these children experienced ocular muscle control problems.

From the literature there appears to be controversial findings debating whether children with DCD also experience ocular motor control problems. According to Mon-Williams *et al.* (1994) and Langaas *et al.* (1998) could poor eye movements contribute to poor motor co-ordination, but no link could be made between ocular motor control and DCD. One could debate that there could be a link between poor ocular motor control and DCD, however it is not clear what the relationship is between DCD and visual problems associated with ocular muscle control. Relatively little research findings with regard to the nature and relationship of ocular muscle control problems with DCD could be found in the literature. The aim of the study was therefore to determine, as ascertained by eye muscle control, what the nature and scope of these problems are in 7 to 8 year-old children diagnosed with DCD.

Materials and Methods

Research design

This study is a follow-up on a research project undertaken in 2006. A pre-test-post-test design was used for this purpose. The first testing was performed in June 2006 (part of the first study) on children (mean age of 83.33 months) aged 6.9 years, whereas the follow-up test was performed one year later in June 2007 on the same children with a mean age of 95.66 months (7.97 years). Ethical approval for this study was provided by the ethics committee (06M04) of the North-West University, Potchefstroom Campus. A discussion with the various headmasters was held where the aim and protocol of the study were explained to them. Children with DCD, whose parents gave permission for them to participate in the follow-up study, were evaluated with regard to DCD and eye muscle control.

Participants

Two grade one classes from each of three primary schools in Potchefstroom in the North-West Province, South Africa were randomly selected to participate in the first part of this study in 2006. The total number of subjects that were identified for the research project was 101 (48 boys, 53 girls) between the ages of 6 to 7 years. The distribution of the subjects was within the various racial groups and proportional within the test sample (37 white, 50 black, 12 coloured children). From the group that participated in the project in June 2006, 49 children (20 boys, 29 girls) were identified without DCD and 52 children (28 boys, 24 girls) with DCD of which 29.30% (n = 29) with moderate DCD and 23.2% (n = 23) with severe DCD. The 52 children who were identified with moderate and severe DCD (≤ 15^{th} and 5^{th} percentile) were approached for further participation in the research project one year after the first study. Of this group, 12 had relocated, and the informed consent forms of another eight children were not returned by the parents. Thirty two subjects (20 boys, 12 girls) were therefore available for the follow-up study. Only the children with DCD, whose parents gave permission for their children's participation in the follow-up study, were evaluated with regard to DCD and visual functioning.

Measuring instruments

Movement Assessment Battery for Children I (MABC-I)

Henderson and Sugden (1992) developed the MABC-I to evaluate the motor development status of 4 to 12 year-old children. This measuring instrument exhibits a good reliability (Leemrijse, Meijer, Vermeer, Lambregts & Ader, 1999). The MABC-I consists of three sub-sections which measure: manual dexterity (MD) (three test items), ball skills (BS) (two test items) and balancing skills (BLS) (three test items); these sub-sections can be scored as three separate sub-scores or combined to obtain a total DCD value. The lower the MABC score, the better the performance in the MABC-test. The test is a norm based measuring instrument that classifies children with severe DCD when their score lies on/or under the 5^{th} percentile. Such children require intervention. When a child's score lies between the 5^{th} and the 15^{th} percentile, he/she is classified at risk for DCD (moderate DCD category) and may need intervention later in life. All the children who fell on or under the 15^{th} percentile participated in the study. When the MABC-total and the values of the three sub-scales are lower, it is an indication of better performance. The various MABC-test items were assessed by the researcher (a trained post-graduate student in Kinderkinetics).

Sensory Input Sifting Measuring Instrument and Quick Neurological Screening Test II (QNST) batteries

Pyfer (1988) developed the Sensory Input Sifting Measuring Instrument which consists of the following test sections: equilibrium, vestibular, reflex, bilateral integration, kinaesthetic and visual test items. This criterion based measuring instrument is suitable for use on all age groups above the age of 6 years (Auxter, Pyfer & Huettig, 1997). Only the visual test items of the aforementioned test battery were used for this study. Vision was analysed by testing the following eye muscle functions: ocular alignment left and right (where the child must focus on an object while one eye is closed), convergence-divergence (the child must focus on an object while the object is moved closer to and away from the nose from a distance of 45cm), fixating with both eyes open as well as with the left and right eye separately from a distance of 45cm away from the nose, and visual pursuit with both eyes open as well as with the left and right eye separately, using a 30cm x 30cm square from a distance of 30cm away from the nose. The visual pursuit of a horizontal as well as a vertical line with both eyes, which is part of the QNST II, was also tested (Mutti, Martin, Sterling & Spalding, 1998).

After the assessment of each one of the ocular muscle control functions, it was then sub-divided into three classes, namely Class 1 – no ocular muscle control deviations; Class 2 – one to three ocular muscle control deviations; Class 3 – more than three ocular muscle control deviations. The following visual deviations were considered less severe deviations and as a result only one point was obtained regardless of more than one of the following symptoms presenting it: eyes that are rubbed, eyes that burn, eyes that are blinked often, eyes that are red as well as tear/watery. In more severe visual deviations the subject obtained one point if any of the following symptoms were present: turning the head to the left or right, moving the head side to side, or up and down during visual pursuit, eyes jumping over the midline, eye jerkiness, eyes not following the object/lose the object.

Data analysis

Data analysis was done using the "Statistica for Windows" (StatSoft, 2010) program. Descriptive statistics was analysed by means of means (M), standard deviations (SD) and minimum and maximum values. A correlation matrix and a two-way variance table were used to analyse the relationship between DCD and the various eye muscle functions.

To determine practical significance, the following guidelines set by Cohen (1988) were used, $d \geq 0.2$ indicated a small practical effect; $d \geq 0.5$ indicated a moderate effect and $d \geq 0.8$ indicated a large effect. Furthermore, a one-way variance of analysis (ANOVA) was used to determine the percentage of children in the various DCD classes who experienced visual deviations. A one-way variance of analysis was also used to determine the percentage of children in the various DCD classes who experienced visual deviations.

Results

Table 1 displays the means obtained in the MABC and the various sub-sections thereof. A correlation matrix and a two-way variance table were used to analyse the relationship between DCD and the various ocular muscle control functions.

Table 2 presents the correlations found between the MABC-total, manual dexterity, ball and balance skills, and the various visual functions controlled by the ocular muscles. Significant correlations with small to moderate practical significance were found between the ocular muscle control and the MABC-total and the sub-sections. Fixation exhibited the highest relationship ($r = 0.65$) with the MABC-total and the various sub-sections. Regarding visual pursuit, fewer correlations were found, as visual pursuit with both eyes only correlated with ball skills with a small practical significance ($d \geq 0.30$).

Visual pursuit with the right and left eye separately, exhibited a small practical significant correlation with the MABC-total, manual dexterity and ball skills, while no correlation with balance skills were found. Visual pursuit of a horizontal or a vertical line exhibited no correlations with the MABC-total or the various sub-sections. Ocular alignment with the right eye exhibited a correlation with a small practical significant effect (d ≥ 0.40) to the MABC-total, manual dexterity and balance sub-sections. Convergence-divergence, as in horizontal and vertical visual pursuit, showed no correlation with the MABC-total or any of the sub-sections.

Table 1: Descriptive information of the group for the MABC-total and sub-sections in the moderate and severe DCD groups

Variables	N	M	SD
MABC-total	**32**	**21.34**	**5.05**
Moderate DCD	2	11.75	1.06
Severe DCD	30	21.98	4.52
Manual Dexterity total	**32**	**8.7**	**2.57**
Moderate DCD	6	5.58	0.49
Severe DCD	25	9.62	2.11
Ball skills total	**32**	**5.52**	**2.68**
Moderate DCD	7	3.86	0.48
Severe DCD	20	7.15	1.69
Static and dynamic balancing skills total	**32**	**7.11**	**2.88**
Moderate DCD	9	6.00	0.61
Severe DCD	17	9.29	1.32

M – Means; SD – standard deviation; N – number of subjects

Table 3 indicates the number of subjects who experienced problems with the various ocular muscle control functions. The subjects were divided into classes according to the number of visual problems that they experienced (Class 1 = no ocular muscle control deviations; Class 2 = one to three ocular muscle control deviations; Class 3 = more than three ocular muscle control deviations). Table 3 furthermore displays the percentage of problems with regard to fixation, visual pursuit, ocular alignment and convergence-divergence, of the subjects in the moderate and severe DCD groups separately.

A very small percentage of the subjects did not exhibit ocular muscle control deviations of any nature. The ocular muscle control deviations varied from 0% to 30% in the various visual functions that were evaluated, and the majority of the subjects fell within Class 3 with regard to ocular muscle control deviations (33% – 83%). Most of the subjects fell in Class 2 with regard to fixation with both eyes and with the right eye separately.

Further analyses showed that during fixation with both eyes and with the left eye separately, 36.67% and 73.33% of the subjects with severe DCD also experienced severe visual problems. However, during fixation with the right eye separately, 60% of the subjects with severe DCD experienced moderate visual problems.

Table 2: Correlations between the various vision functions and the MABC-total and sub-sections

Variables	MABC-TOTAL	MD	BS	BALS
Fixation Both Eyes	0.65**	0.35*	0.31*	0.48*
Fixation Left Eye	0.61**	0.42*	0.36*	0.34*
Fixation Right Eye	0.50**	0.62**	0.03	0.33*
Visual pursuit Both Eyes	0.10	-0.15	0.30*	0.02
Visual pursuit Left Eye	0.28*	0.09	0.20*	0.18
Visual pursuit Right Eye	0.37*	0.31*	0.40*	-0.02
Visual pursuit Horizontal	0.07	0.19	0.11	-0.10
Visual pursuit Vertical	0.01	0.10	0.14	-0.23
Ocular alignment Left Eye	0.09	-0.13	0.37*	-0.02
Ocular alignment Right Eye	0.40*	0.47*	0.22*	0.21*
Convergence-Divergence	0.11	0.14	0.10	0.06

MD – Manual dexterity; BS – Ball skills; BALS – Static and dynamic balancing skills; $d \geq 0.2$*; $d \geq 0.5$**; $d \geq 0.8$***

During visual pursuit with both eyes (76.67%), the right eye (80.00%) and left eye (83.33%) separately, a large scope of severe visual problems (more than three ocular muscle control deviations) were found in the majority of subjects with severe DCD. Only a few of the subjects exhibited little or no visual pursuit problems. With regard to horizontal visual pursuit, 73.33% of the subjects with severe DCD had severe visual problems. Some 36.67% of the subjects with severe DCD also experienced severe visual problems during vertical visual pursuit. Only 33.33% of the subjects experienced moderate and 30.00% no ocular muscle control problems while performing the visual pursuit test.

In most of the cases where children have been diagnosed with severe DCD, they were classified in Class 3 regarding ocular alignment deviations. These percentages varied from 50% to 60%, with the highest percentage problems found in ocular alignment with the left eye.

Discussion

The aim of this study was to determine, as ascertained by ocular muscle control functions, what the nature and scope of visual problems are among 7 to 8 year-old children diagnosed with moderate and severe DCD.

Table 3: Percentage vision functions in different classes in children with moderate and severe DCD

DCD		CLASS 1		CLASS 2		CLASS 3	
	N	%	n	%	n	%	n
			Fixation Both Eyes				
Moderate DCD	2	0	0	0	0	100	2
Severe DCD	30	16.67	5	46.67	14	36.67	11
			Fixation Left Eye				
Moderate DCD	2	50	1	0	0	50	1
Severe DCD	30	3.33	1	23.33	7	73.33	22
			Fixation Right Eye				
Moderate DCD	2	50	1	50	1	0	0
Severe DCD	30	6.67	2	60	18	33.33	10
			Visual pursuit Both Eyes				
Moderate DCD	2	0	0	50	1	50	1
Severe DCD	30	6.67	2	16.67	5	76.67	23
			Visual pursuit Left Eye				
Moderate DCD	2	0	0	0	0	100	2
Severe DCD	30	0	0	16.67	5	83.33	25
			Visual pursuit Right Eye				
Moderate DCD	2	0	0	0	0	100	2
Severe DCD	30	10	3	10	3	80	24
			Visual pursuit Horizontal				
Moderate DCD	2	0	0	0	0	100	2
Severe DCD	30	3.33	1	23.33	7	73.33	22
			Visual pursuit Vertical				
Moderate DCD	2	0	0	0	0	100	2
Severe DCD	30	30	9	33.33	10	36.67	11
			Ocular alignment Left Eye				
Moderate DCD	2	0	0	50	1	50	1
Severe DCD	30	13	4	26	8	61	18
			Ocular alignment Right Eye				
Moderate DCD	2	0	0	0	0	100	2
Severe DCD	30	10	3	40	12	50	15
			Convergence-Divergence				
Moderate DCD	2	0	0	0	0	100	2
Severe DCD	30	30	9	6.67	2	63.33	19

Class 1 – no ocular muscle control deviations; Class 2 – 1 to 3 ocular muscle control deviations; Class 3 – more than 3 ocular muscle control deviations

The results indicate that a relationship exists between DCD and the different ocular muscle control functions as moderate to high correlations were found between the various visual functions (fixation, visual pursuit with left and right eye, and ocular alignment with right eye) and the MABC-total. These correlations support research findings that indicate that visual problems exhibit a relationship with spatial orientation (Mon-Williams *et al.,* 1999; El-Kahky, Kingma, Dolmans & De Jong, 2000; Anand, Buckley, Scally & Elliott, 2003), gross motor deficiencies and poor motor development (Rösblad & Von Hofsten, 1994; Fletcher-Flinn *et al.,* 1997; Lefebvre & Reid, 1998; Aucamp, 2001; Pienaar, 2008) which are symptoms found in DCD children. Fixation, visual pursuit and ocular alignment problems, of which high percentages of problems were indicated in the group, may contribute to various motor- and academic deficiencies (Cheatum & Hammond, 2000). Children who experience problems with fixation, often experience difficulty with reading and writing activities, because they are not able to hold the eyes steady during a reading activity or a writing assignment. Such problems lead to the lost of information, misunderstandings or even distortions. Children with these problems also find it difficult to participate in daily activities and sport, because they cannot keep their focus on the object that are thrown or kicked towards them (Langaas *et al.,* 1998; Wilson & Falkel, 2004; Pienaar, 2008). Researchers indicate that a child who experience problems with visual pursuit, will struggle to read, copy from the board, exhibit a short attention span, will struggle to follow an object on various levels and might experience problems with spatial orientation (Mon-Williams *et al.,* 1994; Langaas *et al.,* 1998; Wilson & Falkel, 2004; Winnick, 2005).

Significant correlations with a small practical effect ($d \geq 0.2$) were found between manual dexterity, fixation with both eyes and with the left eye separately, visual pursuit with the right eye and ocular alignment with the right eye, while a correlation with moderate practical significance ($d \geq 0.5$) was found with fixation with the right eye. The above visual skills (fixation, visual pursuit and ocular alignment) are necessary for reading and writing (Cheatum & Hammond, 2000; Wilson & Falkel, 2004; Pienaar, 2008). It therefore appears that, should these visual skills not be well developed, it could have a negative effect on the child's academic achievements.

All six ocular muscle control functions (visual pursuit with both eyes, and the left and right eye separately, fixation with both eyes and with the left eye, and ocular alignment with the left eye) showed significant correlations with a small practical significance ($d \geq 0.2$) with ball skills. Visual skills are important for a child to participate in sport activities, where it is continuously necessary to follow the object with the eyes so that it can be hit, caught or kicked (Cheatum & Hammond, 2000). These findings also confirm the findings of Sigmundsson *et* *al.* (1997) and Piek and Dyck (2004), which indicate that poor spatial orientation is a common problem among children with DCD. Cheatum and Hammond (2000) are also of the opinion that good visual pursuit and visual perception are required to perform motor activities in the environment.

Although static and dynamic balance exhibited a poor correlation with visual pursuit, it did show a significant correlation with a small practical effect ($d \geq 0.2$) with fixation with both eyes, the left and right eyes separately, and with ocular alignment with the right eye. These findings are in agreement with researchers who have indicated that vision is important in supplying information with regard to spatial orientation, and is therefore essential in regulating balance in challenging situations (El-Kahky *et al.*, 2000; Anand *et al.*, 2003). Fixating the eyes during balancing activities is also important.

The results also indicated that most of the children who experienced severe ocular muscle control problems (Class 3) with regards to fixation with the right eye, visual pursuit with both eyes and with the left and right eye separately, visual pursuit on a horizontal and vertical line, ocular alignment with the left and right eye and convergence-divergence, were also diagnosed with severe DCD. The only two exceptions in this regard were during fixation with both eyes and fixation with the right eye only, where the highest percentage ocular muscle control deviations occurred in Class 2 (moderate ocular muscle control problems).

This research, therefore, confirms a relationship between the ocular muscle control functions of children classified with moderate or severe DCD. Problems with ocular muscle control contribute to academic problems, poor motor skill development and influence fundamental movement skills needed for successful sport participation (Van Noorden, 1976; Auxter *et al.*, 1997; Adler, 2002; Halle, 2002; Wilson & Falkel, 2004; Pienaar, 2008). Strategies should therefore be found to improve such problems among children diagnosed with DCD.

The results of this study should be evaluated taking into account that the study had limitations such as a small group. Generalisation of the results should therefore be done cautiously. Research has shown that maturing tendencies play a role in the development of motor skills (Malina, Bouchard, & Bar-Or, 2004) and in certain visual skills such as visual pursuit at a young age (Gilligan, Mayberry, Stewart, Kenyon & Gaebler, 1981). Subsequently, recommendations for further studies are that more probing research should be done to substantiate the relationship between DCD and ocular muscle control and that a control group should be part of the research in order to evaluate the effect of maturity. The effect of a vision intervention on the DCD status of a child should also be investigated.

Acknowledgements

The authors wish to thank the Department of Education and the headmasters of the schools for their permission to perform this study, as well as the North-West University for the financial assistance which made this research possible.

References

Adler, A. (2002). Efficacy of treatment for convergence insufficiency using vision therapy. *Ophthalmic & Physiological Optics: The Journal of the British College of Ophthalmic Opticians (Optometrists)*, 22(6), 565-571.

American Psychiatric Association. (2000). Diagnostic and statistical manual of mental disorders. 4th ed. Washington DC: Author. 943 p.

Anand, V., Buckley, J.G., Scally, A. & Elliott, D.B. (2003). Postural stability in the elderly during sensory perturbations and dual tasking: the influence of refractive blur. *Investigative Ophthalmology & Visual Science*, 44(7), 2885-2891.

Aucamp, A. (2001). Die verband tussen DCD en selfkonsep by 10 - 12-jarige kinders. Potchefstroom: PU vir CHO. (Ongepubliseerde M-tesis). 91 p. (The correlation between DCD and self-concept in 10 to 12 year old children. Potchefstroom: PU for CHE. (M – *Thesis). p. 91).*

Auxter, D., Pyfer, J. & Huettig, C. (1997). *Principles and Methods of Adapted Physical Education and Recreation* (8th ed.). Chicago, IL: Brown Y Benchmark, p. 605.

Borsting, E., Rouse, M. & Chu, R. (2005). Measuring ADHD behaviors in children with symptomatic accommodative dysfunction or convergence insufficiency: a preliminary study. *Optometry*, 76(10), 588-592.

Bouchard, D. & Tetreault, S. (2000). The motor development of sighted children and children with moderate low vision aged 8 - 13. *Journal of Visual Impairment & Blindness*, 94(9), 564-573.

Cheatum, B.A. & Hammond, A.A. (2000). *Physical activities for improving children's learning and behaviour: A guide to sensory motor development*. Champaign, IL.: Human Kinetics, p. 340.

Coetzee, D. & Pienaar, A.E. (2010). The role of visual functions in persisting developmental coordination disorder (DCD) among 7-year-old children: A follow-up study. *African Journal for Physical,*
Health Education, Recreation and Dance, 16(2), 251-264.

Dewey, D., Kaplan, B.J., Crawford, S.G. & Wilson, B.N. (2002). Developmental coordination disorder: associated problems in attention, learning, and psychosocial adjustment. *Human Movement Science*, 21, 905-918.

Dussart, G. (1994). Identifying the clumsy child in school: an exploratory study. *British Journal of Special Education*, 21(2), 81-86.

El-Kahky, A.M., Kingma, H., Dolmans, M. & De Jong, I. (2000). Balance control near the limit of stability in various sensory conditions in healthy subjects and patients suffering from vertigo or balance disorders: impact of sensory input on balance control. *Acta Oto-laryngologica*, 120, 508-516.

Farrar, R., Call, M. & Maples, W.C. (2001). A comparison of the visual symptoms between ADD/ADHD and normal children. *Optometry*, 72(7), 441-451.

Fletcher-Flinn, C., Elmes, H. & Stragnell, D. (1997). Visual-perceptual and phonological factors in the acquisition of literacy among children with congenital developmental coordination disorder. *Developmental Medicine & Child Neurology*, 39, 158-166.

Geuze, R. & Börger, H. (1993). Children who are clumsy: five years later. *Adapted Physical Activity Quarterly*, 10, 10-21.

Gilligan, M.B., Mayberry, W., Stewart, L., Kenyon, P. & Gaebler, C. (1981). Measurement of ocular pursuits in normal children. *The American Journal of Occupational Therapy*, 35(4), 249-255.

Halle, C. (2002). Achieve new vision screening objectives. *Nurse Practitioner*, 27(3): 15-35, March.

Henderson, S.E. & Sugden, S.A. (1992). *Movement Assessment Battery for Children*. London: The Psychological Corporation.

Hoare, D. & Larkin, D. (1991). Coordination problems in children. *National Sports Research Centre*, 18, 1-15.

Jongmans, M.J., Smits-Engelsman, B.C.M. & Schoemaker, M.M. (2003). Consequences of comorbidity of developmental coordination disorder and learning disabilities for severity and pattern of perceptual-motor dysfunction. *Journal of Learning Disabilities*, 36(6), 528-537.

Kaplan, B.J., Wilson, B.N., Dewey, D. & Crawford, S.G. (1998). DCD may not be a discrete disorder. *Human Movement Science*, 17, 471-490.

Langaas, T., Mon-Williams, M., Wann, J.P., Pascal, E. & Thomson, C. (1998). Eye movements, prematurity and developmental co-ordination disorder. *Vision Research*, 38, 1817-1826.

Leemrijse, C., Meijer, O.G., Vermeer, A., Lambregts, B. & Ader, H.J. (1999). Detecting individual change in children with mild to moderate motor impairment: The standard error of measurement of the Movement ABC. *Clinical Rehabilitation*, 13, 420-429.

Lefebvre, C. & Reid, G. (1998). Prediction in ball catching by children with and without a developmental coordination disorder. *Adapted Physical Activity Quarterly*, 15, 299-315.

Lord, R. & Hulme, C. (1987). Perceptual judgements of normal and clumsy children. *Developmental Medicine and Child Neurology*, 29(2), 250-257, April.

Malina, R.M., Bouchard, C. & Bar-Or, O. (2004). *Growth, Maturation, and Physical Activity* (2nd ed.). Champaign, IL: Human Kinetics, p. 728.

Missiuna, C. (1994). Motor skill acquisition in children with developmental coordination disorder. *Adapted*

Physical Activity Quarterly, 11(2), 214-235.

Mon-Williams, M.A., Pascal, E. & Wann, J.P. (1994). Ophthalmic factors in developmental coordination disorder. *Adapted Physical Activity Quarterly,* 11(2), 170-178.

Mon-Williams, M.A., Wann, J.P. & Pascal, E. (1999). Visual-proprioceptive mapping in children with developmental coordination disorder. *Developmental Medicine & Child Neurology,* 41, 247-254.

Mutti, M.C., Martin, N.A., Sterling, H.M. & Spalding, N.V. (1998). *Quick Neurological Screening Test* (2nd ed.). Novato, CA: Academic Therapy Publications.

Peens, A. (2005). A comparison of different interventions for children with developmental coordination disorder. Potchefstroom: North-West University. (PhD – Thesis), p. 233.

Piek, J.P. & Dyck, M.J. (2004). Sensory-motor deficits in children with developmental coordination disorder, attention deficit hyperactivity disorder and autistic disorder. *Human Movement Science,* 23, 475-488.

Piek, J.P., Dyck, M.J., Niemand, A., Anderson, M., Hay, D., Smith, L.M., Mccoy, M. & Hallmayer, J. (2004). The relationship between motor coordination, executive functioning and attention in school aged children. *Archives of Clinical Neuropsychology,* 19, 1063-1076.

Pienaar, A.E. (1993). Die voorkoms en remediëring van grootmotoriese agterstande by kinders in die junior primêre fase. Potchefstroom: PU vir CHO. (Ongepubliseerde PhD – Tesis), p.227 (The incidence and remediation of gross motor deficiencies in children in the junior primary phase. Potchefstroom: PU for CHE. (PhD – Thesis), p.227).

Pienaar, A.E. (2008). Motoriese ontwikkeling, groei, motoriese agterstande, die assessering en die intervensie daarvan: ŉ Handleiding vir nagraadse studente in Kinderkinetika. Potchefstroom: Noordwes-Universiteit, p. 482 (Motor development, growth, motor deficiencies, the assessment and intervention thereof: Manual for postgraduate students in Kinderkinetics. Potchefstroom: North-West University, p. 482).

Pyfer, J.T. (1988). *Implications of the Neurological System in Motor Development*. Texas: Texas Woman's University. 270 p.

Reimer, A.M., Smits-Engelsman, B.C.M. & Siemonsma-Boom, M. (2000). Development of an instrument to measure manual dexterity in children with visual impairments aged 6-12. *Journal of Visual Impairment & Blindness*, 94(3), 177-188.

Rösblad, B. & Von Hofsten, C. (1994). Repetitive goal-directed arm movements in children with developmental coordination disorders: role of visual information. *Adapted Physical Activity Quarterly,* 11(2), 190-202.

Sherrill, C. (2004). *Adapted Physical Activity, Recreation, and Sport: Cross Disciplinary and Lifespan* (6th ed.). New York: McGraw-Hill, p. 782.

Sigmundsson, H., Ingvaldsen, R.P. & Whiting, H.T.A. (1997). Inter- and intrasensory modality matching in children with hand-eye coordination problems: exploring the developmental lag hypothesis. *Developmental Medicine & Child Neurology,* 39, 790-796.

Schoemaker, M.M., Van Der Wees, M., Flapper, B., Verheij-Jansen, N., Scholten-Jaegers, S. & Geuze, R.H. (2001). Perceptual skills of children with developmental coordination disorder. *Human Movement Science,* 20, 111-133.

StatSoft. (2010). *Statistica for Windows: General Conventions & Statistics*. Tilsa, OK: StatSoft.

Tolla, J. (2000). Follow that bear: encouraging mobility in a young child with visual impairment and multiple disabilities. *Teaching Exceptional Children,* 32(5), 72-77.

Van Noorden, G.K. (1976). Chronic vision problems of school-age children. *Journal of School Health,* 46(6), 334-337, June.

Van Waelvelde, H., De Weerdt, W., De Cock, P. & Smits-Engelsman, B.C.M. (2004). Association between visual perceptual deficits and motor deficits in children with developmental coordination disorder. *Developmental Medicine & Child Neurology,* 46, 661-666.

Willoughby, C. & Polatajko, H. (1995). Motor problems in children with developmental coordination disorder: Review of the literature. *The American Journal of Occupational Therapy,* 49(8), 787-794.

Wilson, T.A. & Falkel, J. (2004). *Sportsvision, Training for Better Performance*. Champaign, IL: Human Kinetics. 173 p.

Winnick, J.P. (2005). *Adapted Physical Education and Sport* (3rd ed.). State University of New York: Human Kinetics, p. 573.

Wright, H.C. & Sugden, D.A. (1996). The nature of developmental coordination disorder: inter- and intra group differences. *Adapted Physical Activity Quarterly,* 13, 357-371.