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Progress in Precursor Skills and Front Crawl Swimming in Children With and Without Developmental Coordination Disorder

Matt Donaldson, Brian Blanksby, and N. Paul Heard

This study investigated swimming performance and the influence of task complexity among children with and without Developmental Coordination Disorder (DCD). Two groups of children were matched by age —11 Controls without DCD and 11 children with DCD. Repeated measures ANOVAs showed that children with DCD performed at a significantly lower level than age-matched controls for all the water competency tasks and front crawl. Both groups improved significantly in water competency and front crawl over the 10 lessons. Significant interactions suggested that children with DCD showed different rates of change during the acquisition of the glide and front crawl. Both groups regressed with increased task complexity. Awareness of motor learning difficulties experienced by children enables teachers, parents, and children to have realistic expectations. A supportive environment for children with DCD will enable them to achieve the important swimming skill competencies and reduce drop-out rates in learn-to-swim programs.

The term DCD describes "a marked impairment in the development of motor coordination" (American Psychiatric Association, APA, 1994, p. 53) that is not primarily due to general intellectual, primary sensory, or motor neurological impairments (Gubbay, 1985). Children with DCD have difficulty performing everyday tasks in home, school, and play environments. The motor behavior of these children is generally qualitatively inferior to typically coordinated children (Larkin & Hoare, 1991; Missiuna, 1994). Movement experiences may be difficult to initiate; children with DCD exhibit poor rhythm and timing and reveal more extraneous movements and inefficient techniques. Children with motor learning and coordination problems often fall behind their peers when learning motor skills.

A few studies have investigated differences in motor skill development in swimming by typically developing children (Blanksby, Parker, Bradley, & Ong 1995; Bradley, Parker, & Blanksby, 1996; Parker, Blanksby, & Quek, 1999), but little insight exists of atypical progressions in children with physical disabilities (Gelinas & Reid, 2000). Such information would enable parent, teacher, and pupil expectations to be aligned realistically for a child learning to swim. If the rate of

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improvement is slower in children with DCD, unrealistic expectations could lead them away from an active lifestyle due to pressures exerted by teachers and/or parents. Understanding how motor skill learning and coordination problems constrain skill development enables learning practices to be devised that better target the needs of children and their likelihood of success.

The paucity of information regarding skill development progressions by children with and without DCD deemed it important to examine differences in water competence levels of children with DCD and age-matched controls. The progress of children with DCD over 10 swimming lessons was compared with typically developing children of similar ages and swimming levels. A measuring scale was created to assess the progress made in front crawl swimming and precursor skills.

Wilson, Kaplan, Crawford, Campbell, and Dewey (2000) developed a parent questionnaire that aimed to reliably identify children with and without DCD, aged between 8 and 14 years. Wilson et al. (2000) correlated the DCDQ with the Movement Assessment Battery for Children Checklist (MABC; Henderson & Sugden, 1992). The DCDQ was found to have acceptable internal consistency ($r = 0.88$) as well as concurrent ($r = 0.59$) and construct validity (Wilson et al., 2000). Then, Boyle (2003) found that the DCDQ was correlated with the MAND motor performance battery ($r = 0.79$; McCarron, 1982) and confirmed that the DCDQ differentiated between children with and without DCD.

Motor Skill Acquisition in Children With DCD

Learning by children with DCD was associated more with task repetition than just maturational experiences (Missiuna, 1994). Insufficient repetition of swimming drills could retard learning, especially if rudimentary movement patterns have been automated. Difficulties in controlling movements when acquiring a motor skill were accomplished by constraining the degrees of freedom during movement performances (Missiuna, 1994; Saltzman & Kelso 1983). Children with DCD increasingly relied on vision while learning a task and this continued once the task was learned (Lord & Hulme, 1988). Teaching methods and instructional strategies for children with DCD should be specific and simple and interspersed with hand signals used for corrective feedback. These instructional strategies are supported by Blanksby and Blanksby (1995) who suggested that a part-part-whole method of teaching, interspersed with corrective feedback, is important for optimal learning in swimming.

Controlling speed, force, timing, and direction of the body and limbs, and difficulties with intralimb and interlimb coordination, occur when children with DCD perform fundamental motor skills (Larkin & Hoare, 1991; Larkin & Parker, 2002). This would result in technique inefficiencies and hinder the rate of progress when learning to swim. Furthermore, if movements appear awkward, one can become frustrated or feel foolish and insecure, leading to a fear of failure and a dislike of physical activities. A meta-analysis of 21 studies that investigated motor skill intervention for children with DCD found that children over the age of 5 responded optimally to task specific intervention in small group settings, especially if performed 3–5 times per week (Pless & Carlsson, 2000). Most information on swimming by children with coordination difficulties or DCD is anecdotal (Larkin

& Hoare, 1991; Whiting, 1970). Gelinas and Reid (2000) found that traditional learn-to-swim progressions were not developmentally valid for most children with motor disabilities such as cerebral palsy.

Optimal Readiness in Learning to Swim

The optimal age for learning front crawl stroking of typically developing young children has been reported as 5.5 years (Blanksby et al., 1995; Erbaugh, 1980). There is evidence that aquatic skills progress similarly through gradual and developmentally-ordered motor sequences of water orientation, water entry, buoyancy, body position, leg action, arm propulsion, breath control, and stroking with combined limbs (Erbaugh, 1978, 1980; Langendorfer & Bruya, 1995; Oka, Okamoto, Yoshizawa, Tokuyama, & Kumamoto, 1978; Roberton, 1977).

Assessment Instruments in Swimming

Aquatic motor sequences can help provide an important type of assessment instrument (Bradley et al., 1996; Langendorfer & Bruya, 1995). The arm propulsion sequence was suggested to shift gradually from no arm action, to short and rapid flexion, and then to an extension push with minimal/limited propulsion, to more progressive push-pulls, and then a more advanced propulsion. The arm recovery sequence consisted of no arm action, to underwater recovery, and then to rudimentary, straight, and bent-elbow arm recovery (Langendorfer & Bruya, 1995).

Erbaugh (1978, 1980, 1986) developed a similar observation rating scale that was modified by Bradley et al. (1996) as the MERS-F. The five sequential developmental progression task levels of the MERS-F were the following: supported beginner kick, independent leg action, beginner front crawl action, front crawl action with breathing, and advanced front crawl action with increased swimming distance (Bradley et al., 1996). The MERS-F established moderate face validity ($r = 0.78$) and high intrarater reliability ($r = 0.98$).

The component approach can help in motor skills such as swimming because large performance variations have been identified (Blanksby et al., 1995; Erbaugh, 1980; Quek, 1996). Blanksby et al. (1995) speculated that high intragroup variability in aquatic skills was attributable to degree of previous swimming experience, motor ability, and fear or love of water. Hence, this study examined rates of progress and skill levels over 10 lessons by children with DCD and a typically developing group of similar ages.

Method

Participants

The participants in this study were 22 children (11 controls, 11 children diagnosed with DCD). The mean ages of the controls and those with DCD were 7.1 ($SD = 0.94$) and 7 ($SD = 0.77$) years, respectively. The children with DCD were recruited from a specialist movement program at The University of Western Australia for children having difficulties in learning motor skills. Human rights clearance and written parental permission were obtained for each child before participation in the study.

Test Instruments

We used the DCDQ to assess the level of coordination of each child relative to other children of the same age. The rating scale ranged from 1 to 5 with a total possible score of 85. The DCDQ reliably identifies children with and without DCD (Boyle, 2003; Wilson et al., 2000). Information about previous swimming experience was obtained from parents via a written questionnaire. Participants were assessed on the (a) front float, (b) glide, (c) independent leg action, and (d) front crawl stroke. The latter aquatic skill was considered to be representative of combined arms, legs, and unilateral breathing. The assessment included an achievement rating and a qualitative descriptive component approach to measure the developmental sequence of the leg action (Bradley et al., 1996; Quek, 1996).

Tasks were rated on a scale of 1 (*achieved*) or 0 (*not achieved*). Then, efficient techniques or problems were identified by using the Larkin and Hoare method (1991). Arm, leg, head, trunk, and coordination components in front crawl, plus front float and glide, were assessed using a 3-point rating scale of zero, one, or two. The rating scale was 0 (*not achieved*), 1 (*inefficiently achieved*), or 2 (*efficiently achieved*). This three-point rating scale provided greater insights into the difficulties experienced in front crawl stroke and increased the sensitivity of measuring the rate of learning over the intervention period (see Table 1).

Visual poolside assessments were made and video recordings were replayed to confirm the scores for each participant. Efficient front crawl stroke and technique problems were noted when participants demonstrated the complex task of integrating arms, kicking, and breathing as representative of front crawl. If participants did not achieve these tasks, they were assessed on their best performances when completing a combined arm and leg action. A second, experienced swimming teacher also rated the swimming progress to further validate the process.

Procedures

Lessons were held in a covered 11m × 25 m pool of depth 0.95 m to 1.4 m, and water temperature ranged from 28.5 to 29.5 °C. Over a two-week period, the participants attended 10, half-hour lessons, which were videotaped from front and side views. Information was documented on assessment sheets regarding the performance level plus the quality of movements performed.

Control group participants were matched in groups of 2–4 pupils of similar ability. Children with DCD were matched according to swimming ability in groups of two based on their initial, unaided swimming performances. Two fully accredited and experienced swimming teachers attended an in-service program directed toward reinforcing instructional strategies, lesson goals and progressions, skills useful for minimizing "technique problems," and class management. Daily sessions were conducted for the participants following the same programs devised for the group with DCD. The same teacher conducted all daily sessions for the control group. Both teachers kept testing conditions similar for each child with similar task sequences.

Table 1 Larkin and Hoare's (1991) Method to Assess Arm, Leg, Head, Trunk, and Coordination Components in Front Float, Glide, and Front Crawl

Coordination Components	Rating Scale		
FRONT FLOAT			
Technique Problems	0	1	2
1. General muscle tension			
2. Does not place the face in the water			
3. The hips are not pushed to the surface			
4. The legs are not pushed to the surface			
5. Extraneous movements with body positioning			
Total Maximum Score = 10			
Efficient Pattern	0	1	2
1. Legs and feet pushed upwards; hips and lower limbs at horizontal			
2. Spreads the legs (like a starfish)			
Total Maximum Score = 4			
GLIDE	0	1	2
Technique Problems			
1. Does not flex lower limbs in preparation for propulsion			
2. Difficulty pushing off from the pool side or floor			
3. Knees/hips flexed			
4. Prone position broken			
5. Legs too low in the water			
6. Legs apart			
7. Arms not extended forward			
8. Poor balance and trunk stability			
9. Feet kicking slightly			
Total Maximum Score = 18			
Efficient Pattern	0	1	2
1. Fast strong extension of the limbs aids propulsion			
2. Horizontal positioning of the body and legs			
3. Head aligned with body and arms extended forward			
Total Maximum Score = 6			
FRONT CRAWL—EFFICIENT PATTERN			
Lower Limbs	0	1	2
1. Kick initiated at the hips			
2. Relaxed feet			
3. Knees extended			
4. Feet just break surface			
Total Maximum Score = 8			
Trunk	0	1	2
1. Body is horizontal in the water			
2. Minimal body rotation			

(continued)

Table 1 *(continued)*

Coordination Components	**Rating Scale**		
Total Maximum Score = 4			
Arms and shoulders	0	1	2
1. Recovery involves initial lift of upper arm, flexed elbow and relaxed hand			
2. Hand enters the water between shoulder and midline of body			
3. Hand exits water at upper thigh level			
4. Back of the hand leads recovery			
Total Maximum Score = 8			
Head	0	1	2
1. Head remains horizontal in water, turns to either side to inhale			
Total Maximum Score = 2			
Coordination	0	1	2
1. Smooth action in which kick contributes to stability and propulsion to stroke			
2. Regular breathing pattern linked to arm action			
3. Fluidity of stroking			
Total Maximum Score = 6			
Total Maximum Score for Efficient Front Crawl Technique = 28			
FRONT CRAWL TECHNIQUE PROBLEMS			
Lower limbs	0	1	2
1. Cyclic action with excessive flexion at the ankle, knee and hip			
2. Excessive flexion of the knee			
3. Initiates the kick from the knee rather than from the hip			
4. Ankles stiff			
5. Ankles not extended			
6. Thighs are abducted			
7. Legs too deep or too shallow			
8. Persistent asymmetry in pattern			
9. Excessive breaking of the water surface with the lower leg			
10. Inefficient leg action			
11. Legs are not used to stabilize arm/shoulder action			
12. Scissoring as trunk twists			
13. Legs trailing—wide apart			
Total Maximum Score = 26			
Trunk	0	1	2
1. Excessive body rotation			
2. Poor trunk stabilization			
3. More vertical than horizontal in water (body position component)			
4. Twisting along vertical axis			
Total Maximum Score = 8			

(continued)

Table 1 *(continued)*

Coordination Components	Rating Scale		
Arms and shoulders	0	1	2
1. Hands slap the water			
2. Inefficient arm extension at water entry and exit			
3. Irregular or asymmetric arm movements			
4. Elbows not high enough during recovery			
5. Uneven pull in arm action			
6. Short underwater pull			
Total Maximum Score = 12			
Head	0	1	2
1. Lifts rather than turns head to inhale			
2. Head position too high/low			
3. Breathing labored			
4. Lifts head forward to breathe			
5. Stands to breathe			
6. Difficulty breathing to nonpreferred side			
7. Inefficient arm extension when breathing			
Total Maximum Score = 14			
Coordination	0	1	2
1. Poor rhythm			
2. Poor timing between arms and legs			
3. Arms not linked to breathing pattern (breathing to wrong shoulder)			
4. General muscle tension			
5. Difficulties pushing off wall—Initiating stroking			
6. Difficulties with breathing and arms			
Total Maximum Score = 12			
Total Maximum Score for Front Crawl Technique Problems = 72			

Administration of the Tests

Verbal instructions and visual cue demonstrations via “hand signals” were used when administering the basic skills and formal stroking. Participants were asked to perform their best swimming through statements such as “Today you need to do your best swimming so that you can move up to the next level.” No buoyancy aids were used during the assessment, and qualitative assessments were made after lessons on days 1, 5, and 10. During testing, two trials were used for each of the glide, combined arm and leg action, and front crawl with breathing. The best trial was used for analysis.

Daily formats of lessons focused on front crawl and back crawl lead-up drills. When front crawl and back crawl were competently performed, participants progressed to breaststroke skill development during the second week of daily lessons. Front crawl was taught using the Uniswim part-part-whole method of teaching with standardized step-by-step progressions (Blanksby & Blanksby, 1995). Verbal and visual feedback was specific to the needs of each individual to facilitate optimal learning. A variety of buoyancy aids (bubbles and kickboards), submersion aids (rubber dinosaurs and colored poles), and stoke mastery aids (kickboards of various sizes) were used to assist with the learning progress.

From a motivational perspective, positive comments were used such as "That was a good effort, but try and point the toes a little more on the way back." If the participant performed a swim at a regressed level, positive aspects from the performance were reinforced with motivational correction (Langendorfer & Bruya, 1995). Constant corrective feedback was given about a specific aspect upon which to concentrate during the next trial. The lessons were finished with a fun activity such as retrieval of dinosaurs from the bottom, treading water, or climbing down a pole to touch/sit on the bottom of the pool.

To obtain individual perceptions of water confidence, the children were questioned after the lessons on days 5 and 10. Children were shown six pictures of faces representative of different ranges of levels of confidence (Quek, 1996). They were first asked, "When I am swimming, do I feel OK, happy or great," followed by "I do not feel good, I feel scared or I feel very scared," and then "When you are swimming, which picture looks most like how you feel when in the water?"

Analysis of Data

Prior to the analysis, all dependent variables were examined via SPSS to scrutinize data entry and underlying assumptions for ANOVA and *t* tests (Coakes & Steed, 2003). Component variables for efficient technique and technique problems were computed to provide measurement by a total approach in front crawl. Levene's tests for equality of variance were performed for each statistical procedure (Coakes & Steed, 2003). Interrater reliability between the two experienced swimming teachers was ascertained from the video recordings. The percentage exact agreement for six participants on days 1 and 10 were calculated for these ratings and attained a 91% agreement rate.

Achievement ratings were used in a 2 (group) × 3 (lessons) factorial ANOVA with repeated measures on the second factor to explore group differences and assess the changes in the front float and glide ratings. The dependent variable, efficient front float, had a maximum score of 4 whereas, in comparison, a maximum score of 10 was possible for the technique problems. The maximum scores possible for the efficient glide and technique problems were 6 and 18, respectively. The components measured for front crawl were the lower limbs, trunk, arms, head, and coordination. Efficient front crawl had a maximum achievable rating of 28, as compared with 72 for front crawl technique problems. Using a front crawl achievement rating, another 2 (group) × 3 (lessons) factorial ANOVA was calculated to identify group differences and changes across days for total efficient technique and technique problem ratings. The maximum attainable score in the development sequence was 5 for the leg action rating (Bradley et al., 1996; Quek, 1996). A significance level of ($p < .05$) was used for all statistical tests.

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Results

DCDQ

Assessment of motor proficiency across a range of tasks using the DCDQ revealed that the group with DCD recorded significantly lower levels of coordination ($t = 3.395$, df = 18, $p = 0.003$) than the controls. The DCD mean rating score was at the lower end of the range for DCD (DCD $M = 50.6$, $SD = 10.7$), while the controls were well within the typical range (Control $M = 66.6$, $SD = 10.1$).

Water Confidence

Water confidence was assessed on days 5 and 10. A 2 (group) × 2 (day) factorial ANOVA with repeated measures on the second factor reported no significant differences between the two groups and the interaction (*p values* = 0.290 and 0.118, respectively). There was a self-perception that water confidence significantly improved from day 5 to day 10 (day 5, $M = 4.59$, $SD = 1.22$; day 10, $M = 5.15$, $SD = 0.93$, $p < 0.046$) for both groups.

Front Float

Analysis of variance of the achievement ratings for efficient performance of the front float showed a significant day effect ($p = 0.028$), with no significant differences between the groups ($p = 0.115$) and no significant Group × Day interaction ($p = 0.934$). A Tukey post hoc analysis showed that day 10 was significantly different from days 1 and 5 ($p < 0.05$; see Table 2). This indicated an improved quality of float performances across the 10 lessons.

Technique problems in the front float revealed a significant day effect ($p = 0.008$) and group effect ($p = 0.034$), but no significant Group × Day interaction ($p = 0.460$). Post hoc analysis revealed a significant difference between day 1 and day 10 ($p < 0.05$; see Table 2). Together, these effects indicated that participants in the DCD group had more technique problems than the controls, but there were also fewer technique problems by both groups across lessons.

Glide

The analyses of efficiency for the glide showed significant Group × Day interactions ($p = 0.019$), day effects ($p = 0.000$) and group differences ($p < 0.001$; see Figure 1). Post hoc analysis demonstrated that performance on day 1 was significantly lower than days 5 and 10 ($p < 0.05$), but there were no significant changes between days 5 and 10 (see Table 2). On day 1, all 9 control participants achieved the glide (with 2 participants absent during the time of testing). Nine participants with DCD achieved the glide but 2 could not. On day 10, all 11 control participants achieved the glide, whereas 9 DCD participants achieved the glide, 1 did not after 10 lessons, and 1 was absent on day 10.

Glide technique problems (Figure 2) exhibited significant Group × Day interactions ($p = 0.032$), day effects ($p < 0.001$) and group effects ($p < 0.001$). The group mean rating scores showed that the group with DCD had significantly more technique problems than the controls, but the interaction indicated that the reduction in technique problems was greater for the group with DCD (see Table 2).

Table 2 Means and Standard Deviations for the Swim Tests Performed by the Two Groups of Swimmers

		Day 1			Day 5			Day 10		
Test	**Group**	***n***	**Mean**	**SD**	***n***	**Mean**	**SD**	***n***	**Mean**	**SD**
Front Float (E)	DCD	11	2.82	1.08	11	3.00	1.18	10	3.27	.65
	Control	11	3.40	.97	11	3.50	.97	11	3.90	.32
Front Float (P)	DCD	11	3.45	2.81	11	2.36	2.62	10	1.73	1.56
	Control	11	1.30	1.34	11	1.10	1.29	11	.40	.52
Glide (E)	DCD	11	2.55	1.51	11	4.09	1.14	10	4.09	1.45
	Control	9	5.22	.67	11	5.33	.87	11	6.00	.00
Glide (P)	DCD	11	6.91	3.81	11	4.73	2.20	10	3.82	2.23
	Control	9	1.67	1.50	11	1.67	1.41	11	.56	.73
Front Crawl (E)	DCD	11	8.73	5.42	11	10.64	5.41	10	12.36	3.26
	Control	11	16.55	4.34	11	19.18	2.48	11	22.09	3.83
Front Crawl (P)	DCD	11	42.50	9.01	11	38.70	7.89	10	37.30	9.43
	Control	11	24.10	6.92	11	16.20	7.93	11	8.80	5.49

Note. E = Efficiency. P = Technique Problems.

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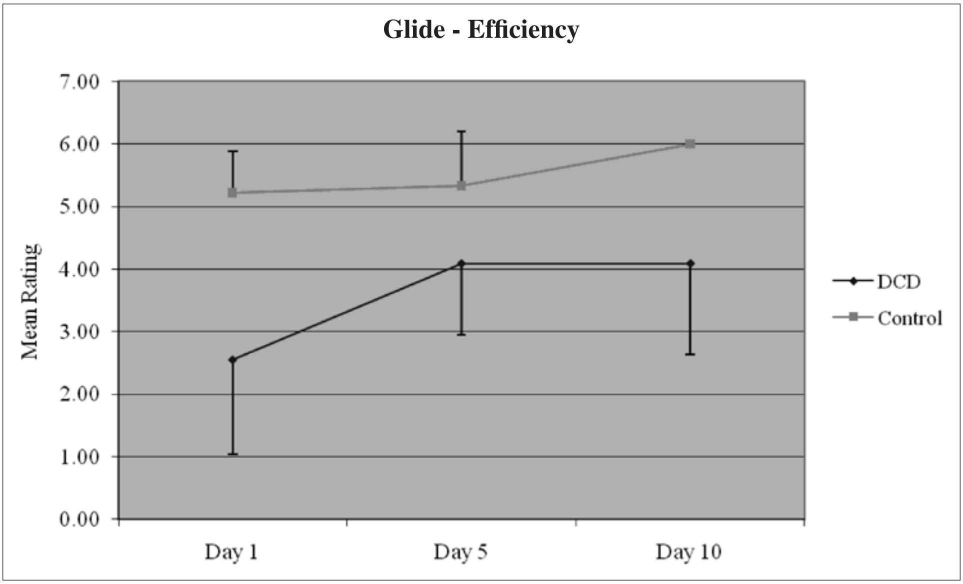

Figure 1 — Group interactions for glide efficiency.

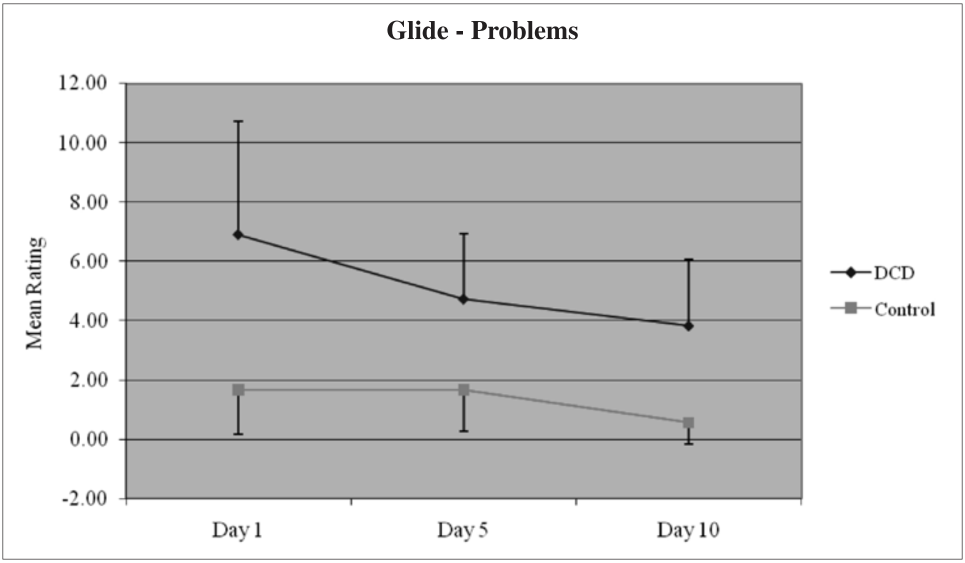

Figure 2 — Group interactions for glide problems.

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Front Crawl Achievement

On day 1, 10 of the 11 controls demonstrated front crawl, and one subject could not perform this complex task. For the DCD group, eight participants achieved front crawl and three could not. On day 10, all 11 controls achieved front crawl whereas 9 DCD participants achieved front crawl and two did not on day 10 (see Figure 3).

The efficient front crawl ratings demonstrated a significant main effect for day ($p < 0.001$) and group ($p < 0.001$), but no significant Group × Day interaction ($p = 0.453$). The mean rating scores showed that the group with DCD had significantly less efficient front crawl than the controls. Post hoc analysis revealed that performance on day 5 was significantly better than on day 1, and performance on day 10 was also significantly better than on days 1 and 5 for both groups (see Table 2).

The front crawl technique problem rating outlined by Larkin and Hoare (1991) revealed a significant Group × Day interaction ($p = 0.028$), day effect ($p < 0.001$), and group effect ($p < 0.001$). Mauchly's test of sphericity (Coakes & Steed, 2003) for population differences was significant ($p = 0.04$) for the front crawl technique problems, but conservative interpretation based on a Greenhouse-Geisser adjustment suggested that the interaction effect was robust. The form of this interaction was such that the reduction in the mean number of problems reported was greater for the control swimmers than for the DCD swimmers across the swimming lessons (see Table 2).

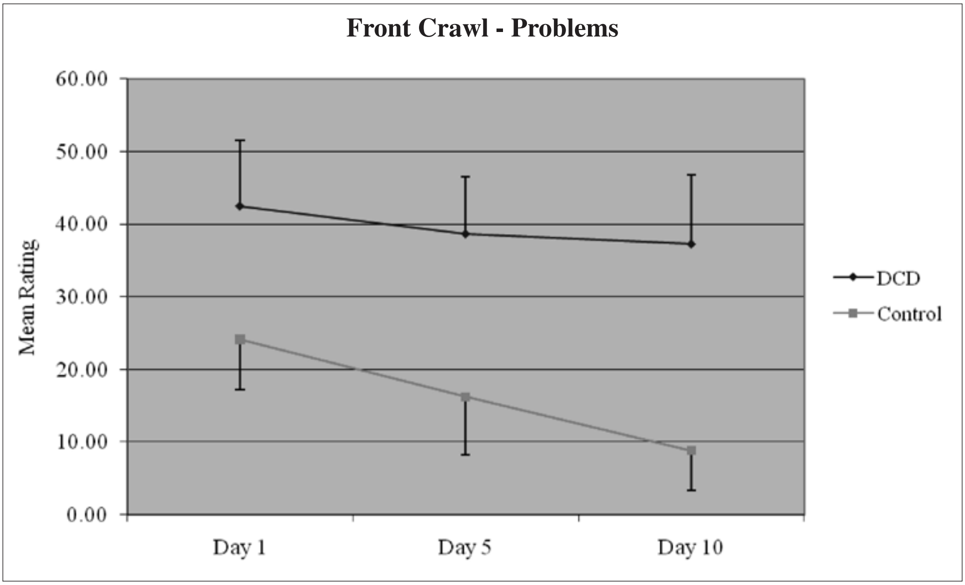

Figure 3 — Group interactions for front crawl problems.

Complexity

It was expected that the two groups would respond differently to increased complexity in interlimb coordination. Therefore, a 2 (Group) × 2 (Complexity) factorial ANOVA with repeated measures on the second factor was performed on the leg action developmental sequence rating scores for independent leg action and front crawl (combined arms, legs, and breathing) technique on day 10. The analysis found significant main effects for group ($p = 0.001$) and complexity ($p = 0.019$), but no significant Group × Complexity interaction ($p = 0.127$). This pattern of results suggests that both groups of swimmers found the front crawl more difficult. However, the DCD swimmers scored lower on all swim assessments when compared with their control counterparts (see Table 3).

Table 3 Means and Standard Deviations for the Independent Leg Action and the Complex Front Crawl Leg Action Performed by the Two Groups of Swimmers

	Torpedo		Front Crawl	
Group	**Mean**	**SD**	**Mean**	**SD**
DCD swimmers	2.55	1.13	1.36	1.21
Control swimmers	4.00	.77	3.82	.60

Discussion

The performance levels for children with DCD were lower in 5 of the 6 measurements than for the controls; namely, the scores for front float technique problems, efficiency and glide technique problems, and efficiency and technique problems in the front crawl stroke were lower for children with DCD. Improvements in front crawl technique problems were slower in the group with DCD. When overcoming glide technique problems to perform an efficient glide, the rate of change was greater for the group with DCD. This could have resulted from the group with DCD commencing with lower baseline skill levels.

Measuring the complexity of just the leg action and performing a full front crawl stroke revealed that both groups regressed in leg action with increased task complexity. The controls performed significantly better on the developmental sequence for leg action rating than the group with DCD. One might have expected that the leg action for the group with DCD would regress more than the controls as the task complexity increased. This was not significant ($p = 0.127$) but the statistical power was low (0.329) and the interaction means showed a trend in that direction.

The group with DCD exhibited more extraneous movements and different body positions during the front float. This agreed with previous reports of general coordination and proprioceptive difficulties reported for children with DCD (Doremus, 1992; Hoare & Larkin, 1991; Licari, 2003; Missiuna, 1994; Smyth & Glencross, 1986; van Dellen & Geuze, 1988). The rating scores for efficient techniques were not significant but the mean scores tended to support the above research. The more frequent problems in the group with DCD indicated the need for a more sensitive delineation between the qualitative performance ratings between the groups.

Children with DCD pushed off the wall with insufficient flexion of the lower limbs to develop propulsion. Children with DCD also demonstrated a lower qualitative glide performance with difficulties controlling leg movements, which were slightly apart, less streamlined, and low in the water, perhaps due to a higher head position. Ineffective propulsion and coordination were reported in children with DCD when running and jumping (Raynor, 1989, 2001*)*.

The controls demonstrated a more efficient front crawl technique performance. All controls could achieve front crawl on day 10, but two DCD participants could not combine arm and leg actions with unilateral breathing. The raw data scores show that the subcomponent total ratings for the leg action, arm action, trunk, head, and coordination were higher in the control group for technique efficiency.

The efficiency criteria ratings indicated that the control group used a more effective and long-legged propulsive leg action by initiating the flutter kicking action at the hips. The knees were extended and the feet were relaxed and just breaking the surface of the water. Some children with DCD used a more rudimentary "cycling" action characterized by excessive flexion at the ankle, knee, and hip and resulted in legs remaining low in the water. This was akin to less experienced and younger children (Langendorfer & Bruya, 1995; Wielki & Houben, 1983) before they progressed to a more advanced flutter kick action (Blanksby et al., 1995; Erbaugh, 1980). Most of the group with DCD displayed less effective leg actions than arm actions. The legs merely trailed and provided little or no propulsion or counter-balancing. This might be a task complexity issue whereby information overload created difficulties with multilimb coordination and contributed to the inefficient leg actions found in children with DCD. Later, this could translate into further problems with most of the components in front crawl, especially the use of a propulsive leg action to maintain a horizontal body position and balance, to decrease resistance, and maintain the mechanics of opposition by limbs, which contribute to these parameters.

The group with DCD was less coordinated with uncontrolled and excessive breaking of the water surface with the lower leg. In addition, they could not stabilize the arm and shoulder actions during stroking. It could be speculated that the less advanced performances by the group with DCD were exacerbated by developmental delay (Cantell et al., 1994), poor muscular strength, more cocontraction (and less ballistic) muscle use in the lower limbs (Raynor, 2001), lower anaerobic capacity (O'Beirne, Larkin, & Cable, 1994), difficulties with inter- and intralimb multilimb coordination (Larkin & Hoare, 1991), or no previous sport opportunities (Bouffard et al., 1996; Cantell et al., 1994).

The controls presented a more horizontal body position than the group with DCD who would encounter increased drag if not horizontal in the water (Langendorfer & Bruya, 1995; Rushall et al., 1994). A child with air in the lungs has a body mass of approximately 1–1.5 kg in the water, and lifting a 5kg head out of the water will exacerbate the rotational effects and cause the legs to drop. The technique problems of the group with DCD demonstrated excessive body rotation when breathing, poor trunk stabilization, a more vertical body positioning in the water, and excessive twisting along the vertical axis. This could be due to poor trunk strength or difficulties with balance, timing, and rhythm (Larkin & Hoare, 1991).

The controls' arm actions were efficient with the back of the hand leading in the recovery and a more forceful final extension during the underwater pull. Children with DCD performed more rudimentary and less propulsive arm actions with short, underwater pulling and hands slapping the water at entry. They exhibited a lower elbow recovery and more irregular and variable movements.

The controls turned their heads to breathe more effectively, but more sensitive criteria might differentiate group differences even further. The group with DCD experienced difficulties with breathing by lifting their heads to the front more consistently, rather than rotating the head sideways to breathe. Generally, labored breathing often prevents swimmers from being able to fully relax and also increases tension and multilimb coordination difficulties. Children with DCD stopped swimming and stood up more than the controls, and they also had more difficulties with maintaining a kicking action when breathing. The coordination criteria included a smooth action in which regular kicking contributed to stability and propulsion in stroking. A regular breathing pattern was linked to the arm action with fluidity of stroking. The controls out-performed the group with DCD in those measures.

Children with DCD performed the complex task of front crawl less effectively, and the levels of skill they reached were significantly less advanced than the controls. Perhaps children with DCD have more problems that "persist" and hinder their rates of learning during the complex combination of arms, legs, and breathing in the total front crawl stroke. This resulted from performing the same number of repetitions as children without DCD. Therefore, children with DCD might require more task repetitions to achieve similar levels of skill as children without DCD (Missiuna, 1994).

Sufficient specific repetitions of a skill are necessary for achieving success at a particular task (Langendorfer & Bruya, 1995). Learning skills in larger class sizes typically found in school swimming programs may lead to children with DCD being unable to keep up with their more typically-coordinated colleagues. A flow-on effect could create lower levels of self-confidence and enjoyment and result in withdrawal from that activity with subsequent social implications. In addition, inexperienced teachers may not provide appropriate corrective feedback required to counter technique problems of children with DCD (Griffin & Keogh, 1982). Missiuna (1994) reported that visuo-motor responses were the same in children with and without DCD. Therefore, swimming teachers should perhaps use visual arm signals to complement verbal cues when providing corrective feedback during swimming lessons. Tactile assistance by actually holding the limb and moving through the desired movement pattern could also be of benefit. The latter could be done on land before entering the water.

This study agreed with Quek (1996) and Blanksby and Parker (1997), who found regression in the developmental sequence of the leg action in typically developing children when the complexity was increased by adding the arm action to the leg and breathing components. Further investigation is warranted because of the low statistical power and nature of the interactions.

The rate of learning scores of children with DCD was similar to that of the controls when measuring efficient front crawl technique and suggested that learning rates between groups were similar. Because the group with DCD performed at a significantly lower skill level on day 1, the number of achievable skills to learn on the "swim continuum" was greater for this group. Conversely, the achievable skills to be learned by the controls were fewer but more complex and required more skillful and controlled movements. This was especially so when comparing the coordination and integration of multiple limbs for the group with DCD to reduce inefficient technique problems. Further longitudinal investigations into the rate of learning for the developmental sequences are required to clarify this issue. A complicating factor remains with the sensitivity of the rating scales. Although these developmental component sequences have been modified and gradually refined, they need further investigation. The learning steps are not equal in their degrees of difficulty and can mask results. For example, putting the face in the water for a scared beginner is a major step in being even able to initiate the learning process. This particular task does not score at all on the scales we used in the current study. Similarly, breathing is a very difficult task but is not weighted very heavily on our scales.

When assuming that all developmental steps are equal, the rates of learning by the DCD and control groups appeared to be fairly similar. The rate of learning for the glide was not greater for the control group than the group with DCD. This was largely attributable to the lower initial performance for the group with DCD and initial high rating scores for the control group. The number of possible "points" achievable for the glide on the "continuum learning curve" was greater for the group with DCD. The differences in initial baseline performance scores made analyzing the rate of learning slightly more complicated; however, a simple effects analysis for the efficient glide shows that the control group continued to learn from day 5 to day 10. The rate of change for the group with DCD leveled off and was unable to score a maximal efficient rating. The control group continued to learn and achieved a maximum achievement score on day 10.

The rate of learning was the same for both groups for the efficient front float. Blanksby and Parker (1997) found that at the age of 4, typically developing children could achieve a proficient front float. Thus, it is not surprising that children aged from 6 to 9 years were able to achieve the front float. A "ceiling effect" was experienced by the control group, who attained an initial high rating on day 1 and the maximum measurement scale rating assessment on day 10. The DCD group scored lower on this measure at both points. Perhaps the rating scale insensitivity influenced the interaction between the groups because the same rate of progress was not possible for the control group.

The results of this study support the typical development sequence for the controls and the group with DCD in learning precursor skills before advanced stroking (Blanksby et al., 1995; Blanksby & Parker, 1997). This finding also supported Gelinas and Reid (2000) who suggested that children with only slight motor difficulties, but who have a relatively high functional capacity, follow similar developmental learning sequences as typically developing children. It appears that children with DCD possibly need more repetitions, visual signals, and other effective teaching strategies, such as tactile assistance, that facilitate skill development in swimming.

The children with DCD did not report lower self-perceptions of water confidence via depicted faces when compared with the age-matched controls (Quek, 1996). This suggests that the children were very comfortable with the teachers and the swimming/learning environment. Hence, it was conducive to skill development, as both groups recorded high self-perceptions for water confidence and low levels of fear. This is important because a major hindrance in learning to swim is fear of the water (Whiting & Stembridge, 1965). In this study, some participants were observed to demonstrate behaviors such as reluctance to fully immerse the face, tense and anxious facial expressions when performing activities, and bobbing movements with feet “glued” to the bottom (Quek, 1996). Participants from both groups made significant progress in becoming even more confident as shown by self perceptions on days 5 and 10.

Despite similar self-perceptions, the group with DCD was less skillful. They were secure in the pool setting, and the quiet “total” pool space enhanced their self-perceptions of water confidence. Furthermore, all children used buoyancy aids during the lessons to alleviate fear of water and allow greater independence and exploration opportunities in the aquatic environment (AUSTSWIM, 1994; Coleman, 2002; Keskinen, 2002). Thus far, studies have not revealed any significant benefits in using buoyancy aids to facilitate learning front-crawl skills in typically developing children (Quek, 1996).

A sensitive measurement tool that can differentiate between high and low self-perceptions of water confidence is important. Otherwise, pushing a child too early could lead to negative experiences and fear and could result in regression within, or withdrawal from, the aquatic environment that provides very important health, fitness, social, and safety benefits (Griffin & Keogh, 1982).

The DCDQ confirmed that the controls and the group with DCD were different relative to movement control and coordination. The DCD group’s mean score was 50.6, which was in the lower range for DCD. The controls’ mean score was 66.6, or well above the DCD range. The DCDQ correlated significantly with the Movement ABC and MAND gross motor proficiency assessment batteries. This indicated an acceptable concurrent validity for discriminating between children with and without DCD (Boyle, 2003; Wilson et al., 2000).

The “plasticity” and rate of progress in consolidating new skills varies between individuals (Langendorfer & Bruya, 1995). This study supports that position because children with DCD were able to perform the precursor skills but had difficulty with the more complex front crawl tasks. Lessons were taught with the teachers out of the water on the pool deck. Whether this is a disadvantage for the DCD group who perhaps respond better with hands on (tactile), proprioceptive teaching could be a topic for further investigation. In addition, manipulating the legs to enable pupils to feel the difference between efficient and inefficient movement habits might also help. On the other hand, greater independence is gained by the pupils being alone in the water; the teachers have a much better view of the action from the pool deck, and the teachers don’t clutter up the water space.

Lessons initially focused on coordinating an efficient kicking action with breathing and arms were introduced later. The effects of previously established inefficient movements are often harder to break than teaching a child to learn to swim correctly from the outset. It is harder to de-automatize inefficient movement patterns that might create difficulties in relearning those which are more efficient. Further research is required of children with DCD and other motor learning difficulties by using participants with no previous swimming experience. There were some positive indications in this study that suggest the rates of learning by children with DCD, albeit a relatively small group with mild DCD, were similar to typically developing children when acquiring swimming skills. Further clarification is required because the group with DCD started from a lower baseline and the linearity of progressions has not clearly been established.

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References

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.

AUSTSWIM. (1994). *AUSTSWIM: The teaching of swimming and water safety*. Melbourne, Victoria: AUSTSWIM Inc.

Blanksby, B.A., & Blanksby, J.P. (1995). The development of an aquatics program in an academic environment. *The ACHPER Healthy Lifestyle Journal, 42,* 9–10.

Blanksby, B.A., Parker, H.E., Bradley, S., & Ong, V. (1995). Children's readiness for learning front crawl swimming. *Australian Journal of Science and Medicine in Sport, 27,* 34–37.

Blanksby, B.A., & Parker, H.E. (1997). Starting age and aquatic skill learning in young children: Mastery of pre-requisite water confidence and basic aquatic locomotion skills. *Australian Journal of Science and Medicine in Sport, 29,* 83–87.

Bouffard, M., Watkinson, E.J., Thompson, L.P., Causgrove-Dunn, J.L., & Romanow, S.K.E. (1996). A test of the activity deficit hypothesis with children with movement difficulties. *Adapted Physical Activity Quarterly, 13,* 61–73.

Boyle, T. (2003). *Assessment tools used to identify children with developmental coordination disorder*. Unpublished Honours Thesis. The University of Western Australia, Crawley.

Bradley, S.M., Parker, H.E., & Blanksby, B.A. (1996). Learning front-crawl swimming by daily or weekly lesson schedules. *Pediatric Exercise Science, 8*(1), 27-36.

Cantell, M.H., Smyth, M.M., & Ahonen, T.P. (1994). Clumsiness in adolescence: Educational, motor and social outcomes of motor delay detected at 5 years. *Adapted Physical Activity Quarterly, 11,* 115–129.

Coakes, S.J., & Steed, L.G. (2003). *SPSS: Analysis without anguish: Version 11.0 for Windows*. Milton, QLD: John Wiley & Sons.

Coleman, R. (2002). Learn-to-swim aids. *Swimming in Australia,* 64-65.

Doremus, W.S. (1992). Developmental Aquatics. Assessment and instructional programming. *Teaching Exceptional Children, Summer*, 6–10.

Erbaugh, S.J. (1978). Assessment of swimming performance of pre-school children. *Perceptual and Motor Skills, 47,* 1179–1182.

Erbaugh, S.J. (1980). The development of swimming skills of pre-school children. In C. Nadeau, et al. (Eds.), *Psychology of motor behaviour and sport* (pp. 324–335). Champaign, IL: Human Kinetics.

Erbaugh, S.J. (1986). Effects of body size and body mass on the swimming performance of pre-school children. *Human Movement Science, 5,* 301–312.

Gelinas, J.E., & Reid, G. (2000). The development of traditional learn-to-swim progressions for children with physical disabilities. *Adapted Physical Activity Quarterly, 17,* 269–285.

Griffin, N.S., & Keogh, J.F. (1982). A model for movement confidence. In J.A.S. Kelso & J.E. Clark (Eds.), *The development of movement control and coordination* (pp. 213–236). New York: Wiley.

Gubbay, S.S. (1985). Clumsiness. In J.A.A. Frederikis (Ed.), *Handbook of clinical neurology, Vol. 2, Neurobehavioural disorder* (pp. 159-167). Amsterdam: Elsevier.

Henderson, S.E., & Sugden, D.A. (1992). *Movement assessment battery for children*. Kent, UK: The Psychological Corporation.

Hoare, D., & Larkin, D. (1991). *Coordination problems in children*. Canberra: Australian Sports Commission.

Keskinen, I (2002). Fear of the water and how to overcome it. *Swimming in Australia,* 64-65.

Langendorfer, S.J., & Bruya, L.D. (1995). *Aquatic Readiness- developing water confidence in young children.* Champaign, IL: Human Kinetics.

Larkin, D., & Hoare, D. (1991). *Out of step: Co-ordinating kids movement*. University of Western Australia: Active Life Foundation.

Larkin, D., & Parker, H.E. (2002). Task-specific intervention for children with developmental coordination disorder: A system view. In S.A. Cermak & D. Larkin (Eds.), *Developmental coordination disorder* (pp. 234–247). Albany, NY: Delmar.[AUQ2]

Licari, M. (2003). *Associated movements in children with developmental coordination disorder.* Unpublished Honours Thesis. The University of Western Australia, Crawley.

Lord, R., & Hulme, C. (1988). Patterns of rotary pursuit performance in clumsy and normal children. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 29,* 691–701.

McCarron, L.T. (1982). *McCarron assessment of neuromuscular development (MAND)*. Dallas, TX: Common Market Press.

Missiuna, C. (1994). Motor skill acquisition in children with developmental coordination disorder. *Adapted Physical Activity Quarterly, 11,* 214–235.

O'Beirne, C., Larkin, D., & Cable, T. (1994). Coordination problems and anaerobic performance in children. *Adapted Physical Activity Quarterly, 11,* 141–149.

Oka, H., Okamoto, T., Yoshizawa, M., Tokuyama, H., & Kumamoto, M. (1978). Electromyographic and cinematographic study of the flutter kick in infants and children. In J. Terauds & E.W. Bedingfield (Eds.), *Swimming III: International series on sports sciences* (Vol. 8, pp. 167–172). Baltimore, MD: University Park Press.

Parker, H.E., Blanksby, B.A., & Quek, K.L. (1999). Learning to swim using buoyancy aids. *Pediatric Exercise Science, 11,* 377–392.

Pless, M., & Carlsson, M. (2000). Effect of motor skill intervention on developmental coordination disorder: A meta analysis. *Adapted Physical Activity Quarterly, 17,* 381–401.

Quek, K.L. (1996). *The use of learning aids in beginning swimming for children.* Unpublished Master's Thesis, The University of Western Australia, Crawley, WA.

Raynor, A.J. (1989). *The running pattern of seven year old children – coordination and gender differences.* Unpublished Honours Thesis, The University of Western Australia, Crawley, Australia.

Raynor, A.J. (2001). Strength, power, and coactivation in children with developmental coordination disorder. *Developmental Medicine and Child Neurology, 43,* 676–688.

Roberton, M.A. (1977). Stability of stage categorizations across trials. Implications for the 'stage theory' of overarm throw development. *Journal of Human Movement Studies, 3,* 49–59.

Rushall, B.S., Holt, L.E., Sprigings, E.J., & Cappaert, J.M. (1994). Re-evaluation of forces in swimming. *Journal of Swimming Research, 10,* 6–30.

Saltzman, E.L., & Kelso, J.A.S. (1983). Toward a dynamical account of motor memory and control. In R.A. Magill (Ed.), *Memory and control of action* (pp. 177–201). Amsterdam: North Holland.

Smyth, R.T., & Glencross, D.J. (1986). Information processing deficits in clumsy children. *Australian Journal of Psychology, 38,* 13–22.

van Dellen, V.T., & Geuze, R.H. (1988). Motor response processing in clumsy children. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 29,* 489–500.

Whiting, H.T.A. (1970). *Teaching the persistent non-swimmer*. London: G. Bell and Sons.

Whiting, H.T.A., & Stembridge, D.E. (1965). Personality and the persistent non-swimmer. *Research Quarterly, 36,* 348–356.

Wielki, C., & Houben, M. (1983). Descriptions of the leg movement of infants in an aquatic environment. In A.P. Hollander, P.A. Huijing, & G. de Groot (Eds.), *Biomechanics and Medicine in Swimming, 14* (pp. 66-71). Champaign, IL: Human Kinetics.

Wilson, B.N., Kaplan, B.J., Crawford, S.J., Campbell, A., & Dewey, D. (2000). Reliability and validity of a parent questionnaire on childhood motor skills. *The American Journal of Occupational Therapy., 54,* 484–493.

Wright, H.C., & Sugden, D.A. (1998). A school based intervention programme for children with DCD. *European Journal of Physical Education, 3,* 35–50.