The Relationship Between Aquatic Independence and Gross Motor Function in Children With Neuro-Motor Impairments

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The purpose of this study was to investigate the relationship between motor performance in the aquatic setting as measured by the Aquatic Independence Measure (AIM) to motor performance on land as measured by the Gross Motor Function Measure (GMFM) and the Pediatric Evaluation of Disability Inventory (PEDI). Forty-nine children with neuro-motor impairments ages 3 to 7 participated in the study. Pearson correlations were applied to determine the relationships between the AIM and the GMFM, PEDI, and Gross Motor Function Classification System (GMFCS). Significant correlations were found between the total AIM and GMFM scores ($r = .69, p < .01$) and PEDI self-care sub-scale ($r = .79, p < .01$) as well as the PEDI mobility sub-scale scores ($r = .35, p < .05$). The water adjustment sub-scale as measured by the AIM showed the strongest relationship to motor performance on land as measured by the GMFM and PEDI in our sample of 49 children.

Increase in motor performance is a main concern of therapeutic interventions for children with motor disabilities. A wide range of therapeutic methods for treating children with neuro-motor impairments has been documented, including among others Bobath (Neuro-developmental treatment), Sensory Integration, Vojta method, neuro-muscular facilitation, strength training, horseback riding, and hippotherapy (Hur, 1995; Siebes, Wijnroks, & Vermeer, 2002). During the last decade, there has been a conceptual shift in the rehabilitation approach for treating children with...
motor disabilities, characterized by a move from the hierarchical view of motor development and control (also known as the neuro-developmental model) to the action system approach (Ketelaar, Vermeer, Hart, Petegem-van Beek, & Helders, 2001; Law et al., 1998; Siebes, Wijnorks, & Vermeer, 2002). While the neuro-developmental approach typically focused on the facilitation of normal movement patterns, the action system approach aims toward mastering a specific functional task in an environmental context (Davis & Burton, 1991; Ketelaar et al., 2001; Newell, 1986; Thelen & Smith, 1994).

Practitioners have become increasingly interested in intervention outcomes that include practical activities, rather than physiological measures such as range of motion and muscle tone for testing functional abilities. This shift has also been acknowledged by the World Health Organization in terms of revising the International Classification of Impairments, Disabilities, and Handicaps (ICIDH) into the newly published International Classification of Functioning, Disability, and Health (ICF; WHO, 2001). Current literature on disability research (Dodd, Taylor, & Damiano, 2002) dealing with the assessment of outcome measures has expressed the expectation that performance enhancement will be addressed according to all the components of the ICF. These include (a) functioning (changes in body functions and structures), (b) disability (changes in capacity and performance that result in activity limitations), and (c) participation (changes in participation, reflecting the psychosocial component of interactions; a replacement term for handicaps in the ICIDH).

Placing emphasis on a functional intervention approach identified the need for an evaluative assessment tool that is sensitive enough to measure functional motor change over time. The Gross Motor Function Measure (GMFM) and the Pediatric Evaluation of Disability Inventory (PEDI) are considered the most reliable and valid instruments in detecting functional change over time (Ketelaar, Vermeer, & Helders, 1998). The GMFM evaluates one’s ability to perform several gross motor functions and is administered by a physical therapist. The PEDI is a functional checklist that can be administered by the child’s caregiver. The GMFM and the PEDI are complementary to one another when trying to get a complete picture of the child in evaluating changes over time (Ketelaar et al., 1998). In terms of the ICF, the GMFM is activity related because it measures functional capacity in five movement domains, assessing the extent to which a child can perform motor skills (Battaglia et al., 2004). The PEDI, which evaluates actual functional abilities in their environmental context, could be categorized as activities and participation both in the mobility and self-care domains, thus reinforcing the use of the PEDI and GMFM as adequate measures for assessing rehabilitation outcomes.

To date, no measure addressing the assessment of function in an aquatic environment for children with neuro-motor deficiencies has been established and widely accepted. In the present study we used the Aquatic Independence Measure (AIM) developed by Chacham and Hutzler (2002) to evaluate aquatic performance. In terms of the ICF, the AIM can be categorized under activity, since it measures an overall estimate of aquatic orientation and locomotor ability. Although this test has been found valid and reliable for children with CP who have exhibited sufficient responsiveness for detecting change over time (Hutzler, Chacham,
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Bergman, & Szeinberg, 1998), no factor structure has been reported. Therefore, in order to address relationships between performance on land and in the aquatic environment, analyzing the factors composing the AIM is required.

Numerous studies have examined whether performance on a specific motor task or physiological abilities could be related to overall motor function. Identifying these abilities and skills can provide a variety of specific therapeutic interventions that may enhance motor function. Parker, Carriere, Hebestreit, Salsberg, and Bar-Or (1993) studied the relationship between the GMFM and physiological fitness of children with CP. Results showed a significant correlation between the GMFM and anaerobic performance in children with CP that was associated with legs ($r = .80, p < 0.005$), but not with the arms ($r = .55, p < 0.05$). Damiano and Abel (1996) examined whether walking ability as measured by the GMFM is related to overall gross motor function. They also investigated which parameters of gait analysis would be most predictive of gross motor functions. Their results revealed a significant correlation between cadence ($r = .793, p < .01$), velocity ($r = .72, p < .001$) and stride length ($r = .60, p < .01$) to the total score recorded on the GMFM. Drouin, Malouin, Richards, and Marcoux (1996) investigated the relation between GMFM scores and walking ability in children with CP and head injuries. Their results also showed a significant correlation between the scores recorded on the GMFM and gait spatiotemporal levels. This significant relationship between gait and the GMFM could be explained by the fact that the majority of the GMFM items require lower extremity mobility and stability skills that are required in walking. Further results showed that the GMFM was more predictive for slow walkers but becomes less discriminative as the child’s gait increased.

Swimming and aquatic interventions have traditionally been viewed as one of the more beneficial activities for children with neuro-motor impairments (Becker & Cole, 2004; Broach, & Datillo, 1996; Harris, 1978). The specific characteristics of the aquatic environment are as follows: (a) The viscosity and hydrostatic pressure of water allows strengthening of weak muscles without overstressing the soft tissue or putting extreme amounts of stress or tension on specific body parts (Becker & Cole, 2004; Broach & Datillo, 1996); (b) The impact of hydrostatic pressure on blood vessels enhances circulation and respiratory activity which in turn maintains general body fitness more efficiently (Becker & Cole, 2004; Gehlsen, Griby, & Winant, 1984; Haung, Viega, Sila, Reed, & Hines, 1989; Hutzler et al., 1998); (c) The warm aquatic environment ($32^\circ-33^\circ$C) and turbulence enhances normal muscle tone, allowing more efficient movement for children with high muscle tone (Becker & Cole, 2004); (d) Buoyancy enables initiation of independent movement possibilities that are difficult to achieve on land due to gravitational restraints (Harris, 1978; Hutzler, Chacham et al., 1998). A number of studies have been conducted in the past ten years comparing mainly physiological aspects of exercise performed on land and in water. The majority of these studies have focused on able-bodied participants (Butts, Tucker, & Greening, 1991; Christie et al., 1990; Darby & Yakel, 2000; Hoeger, Hopkins, & Barber, 1993; Svedenhag & Seger, 1992). Hutzler et al. (1998) studied the effects of a swimming program on vital capacity and water orientation skills in children with cerebral palsy and found that vital capacity improved by 65% in children who participated in swimming sessions, while children who did not engage in swimming sessions improved by 23%.
The main purpose of engaging in aquatic interventions is to enhance functional abilities and independence in daily living (Mackinnon, 1997; Styer-Acevedo & Curillo, 1994). Furthermore, aquatic intervention is considered to be one of the most widely applied types of complementary (to physical, occupational, and speech) therapies for treating children with cerebral palsy (Hurvitz, Leonard, Ayyanger, & Nelson, 2003). Despite previous documentation of the effects of swimming and aquatic interventions (Becker & Cole, 2004; Broach & Datillo, 1996; Dumas & Francesconi, 2001; Geytenbeek, 2002), no evidence has been established regarding the relationship between functional independence in the aquatic environment and gross motor function on land. The purpose of this study, therefore, was to investigate (a) the factor structure of the AIM, (b) the relationship between aquatic performance as measured by the Aquatic Independence Measure (AIM) and gross motor function on land using the GMFM, (c) the relationship between aquatic performance as measured by the AIM and daily life activities using the PEDI, and (d) the relationship between the aquatic performance as measured by the AIM and levels of motor ability using the Gross Motor Function Classification System (GMFCS).

Method

Participants

A correlation cross section design with an intact group aiming at the description of complete groups (rather than sampling; Ary, Jacobs, & Razavieh, 1990) was used in this study. Forty-nine children (F = 21; M = 28) with cerebral palsy (CP) and other related neuro-motor impairments, with an average age of 5.36 (range 3 to 7 years SD = 1.2) years and mean GMFCS score of 3.0 (SD 1.5) participated. Participants included (a) children with CP (n = 39; eight hemiplegia, 11 diplegia, 15 quadriplegia, two athetosis and three ataxia), (b) children with muscular dystrophy (n = 2), and (c) children with non specified neuro-motor deficiencies (n = 8). All children had been placed in two special education kindergartens for children with physical disabilities operated by the Ministry of Education. Both kindergartens operated according to the same educational plan set by the board of education and represented 35% of the total number of children in the district with similar conditions. Therapeutic interventions (i.e., physiotherapy, speech therapy, and occupational therapy) were applied in both kindergartens. In addition, the kindergartens participated in an aquatic program as part of the educational curriculum. All children participated in the aquatic program for a minimum period of five months (a minimum of 40 sessions) to ensure habituation to the aquatic environment and the program structure. Children were included in the study if they met the following criteria: (a) parents signed consent form, (b) pediatrician signed medical consent form allowing participation in aquatic activities, (c) the children had the ability to cooperate and understand simple instruction, and (d) a specified diagnosis of CP or other related neuron-motor impairments was made. The children who participated in the study represented 87.5% of the total number of children attending the kindergartens. All children who met the inclusion criteria participated in the study.
Aquatic Program

The aquatic program took place in the therapeutic swimming pool at the Israel Sport Center for the Disabled in Ramat-Gan, which is operated by the Israeli Parents Organization for Handicapped Children (ILAN). Water temperature was set at 31°-32°C (113°-115°F). Each child received individualized aquatic sessions twice a week by a certified adapted physical education specialist trained in the field of adapted aquatics and hydrotherapy. Individual treatment goals were set in cooperation with the child’s attending physical and speech therapists. Each session consisted of a joint activity of six children with their instructors and lasted 30 min. The aquatic program followed the Halliwick ten point concept targeting functional independence in the aquatic environment (Lambeck & Stanat, 2001a, 2001b). The Halliwick method is a two fold method in which the therapeutic objective is to enhance body awareness and balance control in the aquatic environment by improving abilities such as the ability to transverse to a floating supine position from a standing stance. The second objective of the Halliwick method is to teach independent swimming. Flotation devices are not used in this method. Sessions consisted of three parts: The first five minutes of each session consisted of a structured group activity with six children and their instructors. This part encouraged mental adaptation to the aquatic environment and was accompanied with rhythmic children’s songs that were repeated throughout the program. The second part of the session consisted of a twenty min period during which children practiced individually or in pairs according to treatment goals. The final five min of each session consisted of group activities with children’s songs and was aimed at ending the session and disengaging the children from the aquatic environment.

Instruments

AIM. Three trained adapted physical activity professionals administered the Aquatic Independence Measure (AIM) according to the procedures described by Chacham and Hutzler, 2002. The AIM is a new version of the Water Orientation Scale (WOS; Hutzler et al., 1998), which was developed as an observational tool aimed at assessing the independence in aquatic abilities of children with CP and other related physical disabilities. It has been found to be reliable and valid in assessing children with motor disabilities (Chacham & Hutzler, 2002). In the AIM, function is defined in terms of the child’s ability to perform a given task in a specific test situation. The test is designed to measure performance rather than quality of movement. It consists of 22 items that are essential for achieving aquatic safety and independence. Scores are graded on a scale of zero to four according to the amount of assistance the child requires to perform a given task (0 = does not initiate while 4 = completes task independently without assistive flotation devices). Inter-observer reliability for professionals administering the AIM was verified prior to the experimental procedure. All the adapted physical activity professionals individually viewed a video-tape of seven children with upper motor neuron lesions performing all the items on the AIM and scored each child individually. Parents signed written consent forms allowing their children to be filmed. The test scores between the observers were compared. Results showed a high level of inter-observer
agreement ($r = 0.89$). Children were assessed on the AIM during their scheduled aquatic sessions. All assessments were administered under the same conditions regarding equipment, water temperature, and scheduled adapted physical activity professionals. Professionals did not administer the AIM to children with whom they worked. The administration procedures were as follows: Each child was in the water with his or her instructor, while the administrator was not in the water. The administrator told the instructor the nature of each skill and the child was assessed according to his or her performance of each specific skill.

**GMFM.** Physiotherapists administered the Gross Motor Function Measure (GMFM) to children in their care. All physiotherapists who administered the tests attended a workshop supported by the Israeli Ministry of Education, which trained them to administer it. The GMFM (Russell et al., 1993) is a standardized tool for observing children with cerebral palsy and head trauma, which was developed to measure changes over a period of time. It has been used for assessing children with Down syndrome (Gemus et al., 2001; Martin, 2004; Palisano et al., 2001) and children with motor delays (Kolobe, Palisano, & Stratford, 1998). It has been proven to be reliable and valid (Russell et al., 1989; Russell, Rosenbaum, & Cadman, 1990) and has been used to detect changes in motor function following clinical (Nordmark, Jarnlo, & Hagglund 2000) and therapeutic interventions (Cherng, Liao, Leung, & Hwang, 2004; Ketelaar et al., 2001; Trahan & Malouin, 2002). The 88 items version of the GMFM was administered to all participants in the five dimensions: A (lying and rolling), B (sitting), C (crawling and kneeling), D (standing), and E (walking, running and jumping). Items are scored on a four point scale graded according to the manual (0 = cannot initiate task, 1 = initiates task, 2 = partially initiates, and 3 = completes task). Scores for each dimension were recorded separately, and each child was given a percentage score for each dimension according to the GMFM manual (p. 57). All of the physiotherapists administered the test in compliance with the procedures described by Russell et al. (1993) regarding equipment, environment, and clothing.

**PEDI.** The Pediatric Evaluation of Disability Inventory (PEDI) was administered by a trained adapted physical activity professional. The PEDI (Hayley, Coster, Ludlow, Haltiwanger, & Andrellos, 1992) is a standardized tool for evaluating functional performance based on caregivers’ and therapists’ reports using a structured interview. It has proven to be reliable and valid (Feldman, Haley, & Coryell, 1990; Hayley, Coster, & Faas, 1991; Nicolas & Case Smith, 1996) and to differentiate between children with no disabilities and children with CP (Ketelaar & Vermeer, 1998). It has also been proven to be efficient for documenting changes in function following medical interventions (Bloom & Nazar, 1994; Dudgeon et al., 1994; Mittal et al., 2002; Nordmark et al., 2000) and treatment-based interventions (Ketelaar et al., 2001) in children with CP or related neurological impairments. The PEDI is divided into three content areas: (a) self care, (b) mobility, and (c) social function. The mobility and self-care domains were administered in this study. Physical therapists filled out the mobility domain, and occupational therapists filled out the self-care domain independently.

**GMFCS.** The Gross Motor Function Classification System is a five level system designed to classify severity of motor involvement as portrayed by the degree of
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Gross motor function in children with CP between the ages of 1-12. The system consists of five levels that are based on abilities of independent initiation of movement, with particular emphasis on sitting and walking. Level I is categorized as high functioning with minimum restrictions and no need for mobility devices (such as walker or crutches) whereas Level V is categorized as a child with very limited abilities (Palisano et al., 1997). It has shown inter-rater reliability (.75) for children 2-12 years of age and validity in predicting gross motor performance (Palisano et al., 2000). The GMFCS levels were reported by physical therapists to children under their care.

Procedure

The study was conducted by a team of physiotherapists and adapted physical activity professionals. All tests were administered within a two-week period according to the care-givers’ availability and participants’ scheduled sessions in the aquatic program. Consent forms were obtained from the children’s parents or legal guardians. The study was approved by the ethics committee of the Ministry of Education. All professionals administering the various measures were unaware of test scores until all data were collected.

Data Analysis

Data were analyzed by means of SPSS 11 software. A principal component analysis was used to analyze the AIM structure determining sub-scales and their alpha reliability coefficients. To assess the relationship between the AIM scores and the GMFM and PEDI scores, a two-tailed Pearson product moment correlation was used determining if significant relationships exist between score measures in the following manner: (a) Mean AIM scores were correlated to the mean PEDI self care and mobility scores and to the mean GMFM scores in all four domains; (b) mean sub-scale scores in the different tests were compared, and correlations were viewed between sub-tests to determine whether relationships exist between dimensions in the different test; and (c) the relationship between the degree of disability was measured by means of the GMFCS and the scores were obtained on the AIM, GMFM and PEDI. To assess if the degree of disability, as measured by the GMFCS, differed statistically when performing in the aquatic environment, as measured by the AIM, in comparison to motor performance on land, as measured by the GMFM and PEDI, multiple one way analysis of variance (ANOVA) procedures were performed for each parameter across groups, followed by Scheffe Post Hoc analyses. For all statistical analyses significance was set at $p < .01$.

Results

To determine the AIM structure, a principal component analysis employing Varimax with Kaiser Normalization on the results obtained in the AIM extracted three group components explaining 77% of the variance (Table 1). The three components can be labeled according to their contents as follows: Component 1 — water adjustment skills (Cronbach’s $\alpha = .95$); Component 2 — prone rotating and swimming skills (Cronbach’s $\alpha = .94$); and Component 3 — floating skills (Cronbach’s $\alpha = .87$).
Table 1  Rotated Component Matrix With Item Loading of the AIM

<table>
<thead>
<tr>
<th>AIM Items</th>
<th>Components (sub-scales)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W4 Walking across the pool (3m’)</td>
<td>.90</td>
</tr>
<tr>
<td>W1 Entering the water to a safe position</td>
<td>.90</td>
</tr>
<tr>
<td>W18 Exiting the water</td>
<td>.89</td>
</tr>
<tr>
<td>W3 Walking in shallow water while holding the pool side rail, with one hand</td>
<td>.88</td>
</tr>
<tr>
<td>W9 Holding on a floatation device, in prone position, and executing 3-4 propelling movement with the legs</td>
<td>.71</td>
</tr>
<tr>
<td>W5 Exhaling into the water (blowing bubbles) 5 consecutive times.</td>
<td>.70</td>
</tr>
<tr>
<td>W6 Submerging the entire face in the water without holding the side rail</td>
<td>.62</td>
</tr>
<tr>
<td>W11 Rotating from prone float (5 sec) to a standing position.</td>
<td>.60</td>
</tr>
<tr>
<td>W2 Holding the pool side rail without touching the pool floor</td>
<td>.60</td>
</tr>
<tr>
<td>W15 Jumping into the pool from a sitting position and obtaining a secure position in the water</td>
<td>.59</td>
</tr>
<tr>
<td>W19 Rotating from prone to supine position</td>
<td>.005</td>
</tr>
<tr>
<td>W8 Maintaining a static prone float position</td>
<td>.17</td>
</tr>
<tr>
<td>W22 Advancing in deep water, while performing classic or breast back-stroke</td>
<td>.26</td>
</tr>
<tr>
<td>W20 Rotating from supine to prone position</td>
<td>.12</td>
</tr>
<tr>
<td>W21 Advancing in deep water, while performing crawl or breast back-stroke</td>
<td>.28</td>
</tr>
<tr>
<td>W17 Advancing safely and independently in the water, without the feet touching the pool floor</td>
<td>.55</td>
</tr>
<tr>
<td>W16 Retrieving an object from the pool floor (1m’)</td>
<td>.50</td>
</tr>
<tr>
<td>W14 Shifting from a standing or independent position to a prone float</td>
<td>.54</td>
</tr>
<tr>
<td>W13 Shifting from a standing or independent position to a back float</td>
<td>.34</td>
</tr>
<tr>
<td>W7 Maintaining a static back float</td>
<td>−.16</td>
</tr>
<tr>
<td>W12 Shifting from a back float position to an independent standing or vertical position</td>
<td>.44</td>
</tr>
<tr>
<td>W10 Holding a floatation device, in supine position, and executing 3-4 propelling movement with the legs</td>
<td>.51</td>
</tr>
</tbody>
</table>
Relationships between test scores in the different measures recorded across participants are presented in Table 2. Significant correlations were found between the total AIM scores and the total GMFM scores \((r = .69, p < 0.01)\). Mean scores recorded for the PEDI were viewed in reference to the scaled score. Significant correlations were obtained between the total self care domain of the PEDI \((r = .79, p < 0.01, n = 49)\) and the total mobility domain of the PEDI \((r = .69, p < 0.01)\) to the total AIM scores.

The results between GMFM dimensions and AIM subscales are presented in Table 3. All GMFM dimensions were significantly correlated with the water adjustment skills sub-scale of the AIM (Table 3). The strongest relationships were obtained between the total GMFM scores and the water adjustment skills sub-scale of the AIM \((r = .79, p < 0.01)\). Weaker relationships were found between the floating skills and rotations and swimming skills of the AIM sub-scales to the scores obtained in the dimensions of the GMFM.

Relationship between specific items of the AIM and the dimensions of the GMFM and PEDI are presented in Table 4. Walking across the pool \((r = .78, p < 0.01)\), entering \((r = .75, p < 0.01)\), and exiting \((r = .76, p < 0.01)\) the pool were found to be significantly related to dimensions D and E of the GMFM. Jumping into the water also showed a significant relationship to dimensions D \((r = .40, p < 0.01)\) and E \((r = .39, p < .01)\) of the GMFM.

When assessing correlations between the GMFCS and total test scores of AIM, GMFM, and PEDI, negative relations were expected (Palisano et al., 2000) since the high values of the GMFCS represent low functional abilities (i.e., level V is the lowest level of motor functioning). The GMFCS revealed significant correlations with the total GMFM \((r = -.91, p < 0.01)\) and PEDI \((r = -.89, p < 0.01)\) scores as well as significant correlation with the AIM \((r = -.62, p < 0.01)\) scores.

In assessing the correlations between the GMFCS and the AIM subscales, water adjustment was significantly related \((r = -72, p < 0.01)\) to the GMFCS. Floating \((r = -47, p < 0.01)\) and rotating and swimming \((r = -.47, p < 0.01)\) subscales of the

**Table 2** Correlation Between the AIM Scores to the GMFM and PEDI Normative and Scaled Test Scores.

<table>
<thead>
<tr>
<th></th>
<th>AIM</th>
<th>Water adjustment skills</th>
<th>Floating skills</th>
<th>Rotations &amp; swimming skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMFM scores</td>
<td>.69**</td>
<td>.79**</td>
<td>.49**</td>
<td>.48**</td>
</tr>
<tr>
<td>PEDI-Mobility normative scores</td>
<td>.35*</td>
<td>.36*</td>
<td>.20**</td>
<td>.32*</td>
</tr>
<tr>
<td>PEDI-Mobility scaled scores</td>
<td>.69**</td>
<td>.80**</td>
<td>.53**</td>
<td>.48**</td>
</tr>
</tbody>
</table>

*Note.* **correlation is significant at the 0.01 level, * correlation are significant at the 0.05 level.
AIM also showed significant relationship to the GMFCS. Significant inter-group differences \((p > 0.05)\) are present across the level of function, as categorized by the GMFCS and post hoc analyses, differing significantly between levels in the AIM and GMFM but not in PEDI scores. Statistical analysis of level II of the GMFCS was not included due to a small number of children \((n = 3)\) in this group.

### Discussion

The focus of this study was to investigate the relationship between functional independence in the aquatic environment as measured by the AIM to gross motor function as measured by the PEDI and GMFM in children with neuro-motor impairments. The structure of the AIM was analyzed revealing three identifiable subscales (range of Cronbach’s \(\alpha .95 – .87\). This finding confirms the internal validity of the AIM. This test appears applicable to determining children’s aquatic independence together with the findings previously reported by Chacham and Hutzler (2002) regarding the test’s external validity (significant difference across groups according to the severity of disability) and its test-retest and inter-rater reliability (ICC = .97 and ICC = .99, respectively).

Our sample of 49 children with a range of functional abilities and aquatic function, as represented by the AIM scores, exhibited a significant relationship with the total GMFM and PEDI scores. The GMFM and PEDI scores in the mobility
Table 4  Correlations Between Mobility Domains of the GMFM and PEDI in Relation to Elements of the AIM

<table>
<thead>
<tr>
<th>N = 49</th>
<th>GMFM Dim. D standing</th>
<th>GMFM Dim. E Walking, running &amp; jumping</th>
<th>PEDI Indoor locomotion</th>
<th>PEDI Indoor locomotion distance</th>
<th>PEDI Outdoor locomotion (ODL)</th>
<th>PEDI ODL distance</th>
<th>PEDI ODL surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>W4 walking across the pool</td>
<td>.78</td>
<td>.64</td>
<td>.68</td>
<td>.71</td>
<td>.68</td>
<td>.69</td>
<td>.69</td>
</tr>
<tr>
<td>W3 Walking in shallow water while holding the pool side rail</td>
<td>.66</td>
<td>.56</td>
<td>.70</td>
<td>.76</td>
<td>.69</td>
<td>.68</td>
<td>.72</td>
</tr>
<tr>
<td>W1 Entering the pool</td>
<td>.75</td>
<td>.67</td>
<td>.67</td>
<td>.65</td>
<td>.68</td>
<td>.66</td>
<td>.65</td>
</tr>
<tr>
<td>W18 Exiting the pool</td>
<td>.76</td>
<td>.67</td>
<td>.69</td>
<td>.68</td>
<td>.65</td>
<td>.70</td>
<td>.68</td>
</tr>
<tr>
<td>W15 Jumping into the water from a sitting position</td>
<td>.40</td>
<td>.39</td>
<td>.52</td>
<td>.51</td>
<td>.49</td>
<td>.49</td>
<td>.46</td>
</tr>
</tbody>
</table>

*Note: All correlations significant at the 0.01 level.*
domains also showed a significant relationship to the AIM measure. The self-care domain of the PEDI scores showed a significant relationship to the AIM scores.

The water adjustment sub-scale showed the strongest relation to the GMFM and PEDI scores in terms of the AIM sub-scale. This finding is of special interest since the relationship refers to AIM items that are specifically exhibited in the GMFM and PEDI mobility scales, such as walking, jumping, entering, and exiting the pool. From a dynamics system perspective, the manipulation of control parameter, such as weight bearing in the aquatic environment, could trigger pattern generators and impede walking ability. It must be noted that children moved at a water depth of chest level, thus bearing 25% of their body mass (Becker & Cole, 2004). One example for using gravity as a control parameter was reported by Clark and Philips (1993) who had added ankle weights in infant new walkers in order to elicit a more mature pattern of shank thigh coordination. In the aquatic environment, weight bearing can be controlled by altering the two main forces that affect the posture of the body, which are gravity and upthrust (Becker & Cole, 2004; Lambeck & Stanat, 2001a). When walking in the water, the water upthrust pushes the thigh upward, triggering the stance pattern.

Based on the significant relationships obtained between AIM items (Table 4) such as walking across the pool (W4), entering and exiting the pool (W1, W18) in relation to Dimension D of the GMFM and indoor locomotion of the PEDI, it is suggested to investigate whether improvement of these skills in the aquatic environment may lead to improved function on land (Mackinnon, 1997; Thorpe & Reilly, 2000).

Swimming and Rotating Skills

Low but significant correlations were found between the swimming and rotating sub-scale of the AIM to the PEDI ($r = 0.48, p = 0.01$) and GMFM ($r = 0.48, p = 0.01$) scores. These findings may reflect the variation in level of acquisition of aquatic skills. Swimming and rotating skills require the child to be in a prone or supine position and propel in a coordinated pattern using both upper and lower extremities across a certain distance. These motor patterns are infrequently required in the land environment and need to be learned specifically, within an aquatic environment. Furthermore, the aquatic setting can be characterized as an open dynamic environment that is considered among the most difficult learning conditions (Shumway-Cook & Woollacott, 2000). An additional factor that could lead to the low relationship is that the multi-limb coordination required for both rotation and swimming skills is not exhibited in the GMFM and PEDI mobility section, which mainly involve the use of the lower extremities. Approximately 53% ($n = 26$) of our sample comprised children with severe impairments of their lower limbs. These children have to rely mainly on their upper limbs for movement in the aquatic environment. Parker et al. (1993) reported correlations ($r = .34$) between the anaerobic arm test and the GMFM measure, further supporting this assumption.

Floating

The relationship between the AIM floating skills subscale to the GMFM and PEDI were significant ($r = .49; r = .51 \ p < .01$). These results may be explained in two ways. First, children with severe levels of disability have exhibited relatively good
floating skills. Floating skills are dependent on body density, which is a function of bone, muscle, and fat mass. Respectively, the higher the fat mass, the easier it is to float. Research has found that children with CP have higher fat mass (van den Berg-Emons, van Blaak, & Westerterp, 1998) and a lower bone mass percentage (Henderson, Lin, & Greene, 1995) in comparison to able bodied peers. Furthermore, it may be assumed that the structural changes following the sedentary life style of these children (Longmuir & Bar-Or, 2000) account for accumulating fat mass leading to their relatively good floating abilities. Second, floating skills require a relative steady degree of muscular activation. This activation is impaired due to the abnormal muscle tone affecting the development of movement and causing inappropriate compensation that further impedes development (Parker et al., 1993). Imbalance in muscle coordination makes it very difficult to maintain static floating positions and requires a degree of coordination of which most children with neuro-motor impairments and particularly children with cerebral palsy are incapable.

**GMFCS**

Both GMFM and AIM revealed significant differences across GMFCS levels. This finding is supported by the significant relationships found between both measures. The lowest correlation was found between the GMFCS and the total AIM scores \(r = -.62, p < .01\) in contrast to the relations of GMFCS and the GMFM \(r = -.92, p < .01\). This finding suggests that a child with a low function on land may show good function in the aquatic environment. Figure 1 depicts the distribution of AIM results across GMFCS categories and shows relatively good function in levels three and four.

![Figure 1 — AIM results according to GMFCS levels.](image-url)
This assumption was supported by the results obtained in the floating skills and rotation and swimming skills factors ($r = -0.40$). These results explain the low correlations obtained when comparing the GMFM and floating skills and rotation and swimming skills factors of the AIM, since higher correlations were obtained between the GMFM and GMFCS. Significant relationships appeared when comparing the water adjustment skills to the GMFCS ($r = -0.73$). These strong relations between this sub-scale of the AIM to the GMFM are consistent throughout the results.

In summary, based on our sample of 49 children, the following conclusions are proposed: (a) The AIM can be divided into three factors explaining 77% of variance between the different items of the test. (b) Significant relationships (range $r = 0.69$ to $r = 0.80$) exist between the aquatic (AIM) and the land based measures (GMFM & PEDI). These relationships strengthen if only water adjustment skills are taken into consideration. (c) Children with more severe motor dysfunction, as categorized by the GMFCS, may exhibit better motor performance in the aquatic environment, relative to their performance on land. Research is warranted to investigate whether aquatic interventions may affect motor function on land in children with neuro-motor impairments.

References


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Acknowledgment

This study was funded by Mofet Research Institute in Israel. This article is based on part of the first author’s doctoral studies at the Utrecht University, faculty of Educational Sciences.