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RESEARCH REPORT

Aquatic aerobic exercise for children with cerebral palsy: a pilot intervention study

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Abstract

Purpose: The primary purpose of this pilot study was to evaluate the effectiveness of a14-week aquatic exercise program on gross motor function and walking endurance in children with cerebral palsy (CP). The secondary purpose was to evaluate changes in functional strength, aerobic capacity and balance. *Method*: A prospective time series group design consisting of four measurement sessions (two baseline, one post intervention, and 1-month follow-up) was used. Eight ambulatory children ages 6–15 years with CP and classified at Gross Motor Function Classification System Level I or Level III participated in an aquatic aerobic exercise program. *Results*: Significant improvements were observed for the primary outcomes of gross motor function and walking endurance. No significant differences between any of the secondary measures were observed, although all of the measures demonstrated trends of improvement after intervention. *Conclusion*: Ambulatory children with CP may improve their gross motor skills and walking endurance after an aquatic exercise program held twice per week for 14 weeks, utilizing moderate-to-vigorous exercise intensity and consisting of functional activities.

Keywords

Aerobic exercise, aquatic exercise, aquatic therapy, cerebral palsy, fitness intervention

History

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Introduction

Children with cerebral palsy (CP) often have decreased: gross motor skills (Hanna et al, 2009); walking endurance (Thompson et al, 2008); muscle strength (Thompson, Stebbins, Seniorou, and Newham, 2011); aerobic capacity (Verschuren, Bloemen, Kruitwagen, and Takken, 2010); and balance (Woollacott and Shumway-Cook, 2005). The goals of pediatric physical therapy (PT) intervention for children with CP are to reduce the effects of these impairments and activity limitations and ultimately increase participation. Preliminary evidence on aquatic-based PT intervention suggests that strengthening and aerobic conditioning incorporated into task-based activities may be an effective intervention for improving activity level outcomes in children with CP (Fragala-Pinkham, Dumas, Barlow, and Pasternak, 2009; Retakar, Fragala-Pinkham, and Townsend, 2009; Thorpe, Reilly, and Case, 2005). Task-based or task-specific therapy interventions are founded on motor learning concepts and involve practicing functional tasks such as standing, walking and running (Salem and Godwin, 2009; Valvano and Rapport, 2006).

Over the past few years, aquatic PT intervention has gained popularity. Performing functional activities and exercises in water may be beneficial to children with CP to improve fitness and function because the properties of water reduce excessive joint loading and promote strengthening while at the same time providing assistance to help support children with decreased postural control and muscle weakness (Kelly and Darrah, 2005). Children often perceive the aquatic environment of the pool as a fun environment which can be helpful in motivating children with CP to participate in an exercise program.

Although aquatic PT intervention has many potential benefits, little research is available on its effectiveness. We are aware of six studies investigating aquatic exercise programs for children with disabilities in which at least half of the participants had a diagnosis of CP. One case series (Fragala-Pinkham, Dumas, Barlow, and Pasternak, 2009), two single subject design studies (Kelly et al, 2009; Retakar, Fragala-Pinkham, and Townsend, 2009), two small group quasi-experimental design studies (Ballaz, Plamondon, and Lemay, 2011; Thorpe, Reilly, and Case, 2005) and one non-randomized control study which compared a combined aquatic and land-based physical activity program to conventional Bobath physical therapy (Hutzler, Chacham, Bergman, and Szeinberg, 1998) have been published. Overall the evidence is limited due to the small sample sizes ($n = 1$–11) and design (mostly case reports and single subject) of the studies. The one larger study by Hutzler, Chacham, Bergman, and Szeinberg (1998) that did include a comparison group combined aquatic intervention and land-based activities so it is difficult to determine the effects of the aquatic program alone. In addition, that study evaluated the effects of water exercise on vital capacity and water orientation skills and did not evaluate carryover to land-based activities of gross motor function or walking skills.

The other two group studies by Ballaz, Plamondon, and Lemay (2011) and Thorpe, Reilly, and Case (2005) used a quasi-experimental design without a baseline measurement

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period. In addition, Ballaz, Plamondon, and Lemay (2011) focused on swimming activities instead of task-based aquatic activities and resulted in improvements only at the body function structure level (gait efficiency) and not at the activity level. Thorpe, Reilly, and Case (2005) focused on a combination of lower body exercises and task-based activities of walking and running but did not specify the training intensity parameters or how much time was spent in each of the activities, making it hard to replicate. Overall, these six studies provide preliminary evidence to suggest that aquatic exercise 2–3 times per week for 6–14 weeks may be effective in improving activity or body function and structure level outcomes for ambulatory children and youth with CP. Further evidence is needed to guide physical therapy practice. Specifically, information on training intensity and the effects of aquatic exercise on carry-over of function on land for children with CP are required.

Aquatic physical therapy intervention consists of many components and is individualized to the abilities, needs and goals of each patient. Therefore, it is difficult to conduct a group intervention consisting of different strategies and intensities of activities. So, for this pilot study we designed an aquatic exercise program that targeted aerobic capacity and muscular endurance using primarily task-based activities which were similar for each subject but were adapted to meet the abilities of each subject and challenge them according to their abilities. Hence, a child who had higher fitness at baseline would be challenged at a level that may be too difficult for a child who had lower fitness at baseline. In this study, we examined the effects of this focused aquatic exercise program at both the activity level and the body function and structure level. Each participant took part in individual intervention sessions. All interventions were designed with the same strategies and activities and were dosed at a moderate to vigorous exercise intensity level. The primary purpose of this study was to evaluate the effectiveness of this 14-week aquatic exercise intervention program on improving gross motor function and walking endurance in children with CP. The secondary purpose was to evaluate the effects of this program on functional strength, aerobic capacity and balance.

Methods

Participants

A convenience sample of eight ambulatory children with CP with a mean age of 10.6 years (SD 3.5) participated in this study. The majority of the sample was White/non-Hispanic ($n = 5$; 62.5%) with one child (12.5%) representing each of the following race/ethnicities: Asian; Black; and White/Hispanic. Three children were classified at Gross Motor Function Classification System Level I and five were classified at GMFCS Level III (Palisano, Rosenbaum, Bartlett, and Livingston, 2008). All of the children scored below the normal range on the Mobility Domain of the Pediatric Evaluation of Disability Inventory - Computer Adaptive Test (PEDI-CAT) software version 1.2 (Haley et al, 2011), indicating that their mobility skills of transfers, walking, running and other gross motor skills were significantly decreased compared to peers without disabilities. One child scored in the <2nd percentile on the Social/Cognitive Domain of the PEDI-CAT. The other participants scored in the normal range indicating that the majority were functioning at or above the level of their peers on social and cognitive functional abilities. Specifically, the PEDI-CAT Social/Cognitive Domain addresses communication, interaction, safety, behavior, play, attention and problem-solving skills. The PEDI-CAT is a valid, norm-referenced measure which provides both normative and scaled scores for each domain (Dumas and Fragala-Pinkham, 2012; Dumas et al, 2012; Haley et al, 2011). It was used in this study to provide a description of the participants' functional skills.

All participants met the following inclusion criteria: (1) diagnosis of CP and able to walk independently with or without an assistive device; (2) ages 6–18 years; (3) medically able to participate in an exercise program; (4) able to follow directions and adhere to the exercise program; (5) no anticipated changes in medications or rehabilitation services during the study; and (6) willingness to enter the water with no specific swimming ability required. Children who had a recent history of botulinum toxin injections within 3 months or orthopedic surgery within 6 months of the initiation of the study were excluded from participating. Children with open wounds or swallowing precautions were also excluded from the study. Participants were recruited through Franciscan Hospital for Children's outpatient therapy and clinic programs and through electronic flyers sent to physical and occupational therapists at local public schools. This study was approved by the Institutional Review Board at Franciscan Hospital for Children and the participants and their parents provided written assent or consent. Table 1 provides demographic information on the participants. Table 2 provides information about each participant's current and previous physical therapy services, general participation in sports/active recreation during the study period and swimming ability at the start of the study period. None of the participants received outpatient physical therapy services during the study period.

All of the participants were able to follow directions and adhere to the exercise program with individual support; however, two children had difficulty participating at the specified high exercise intensity for extended periods for many of the sessions. They required considerable encouragement and needed more modification for activities due to decreased attention for Child 1 and child-reported ''lack of interest'' in exercise for Child 2.

Design

A prospective, time series group design consisting of four measurement sessions was used. Outcomes were measured twice during the baseline before the intervention was initiated, once at the end of the 14-week intervention, and once one month after the intervention ended. The initial baseline period was used to control for changes anticipated with maturation, testing and other environmental factors. The baseline ranged from 3 to 4 weeks for 7 children and 11 weeks for one child who could not return at the agreed time for the second baseline session due to the opportunity to go to an overnight camp. The one-month follow-up provided information about whether the children had maintained gains for a month after intensive intervention.

Outcome measurement

Three pediatric physical therapists experienced in administering standardized tests to children with disabilities carried out the testing. The therapists were masked to the study design, did not provide aquatic intervention to any of the participants and did not have access to previous test data. Whenever possible the same therapist completed all the testing for one child. The same order of testing was followed for all sessions and testing took 2 to 2.5 hours to complete. For the baseline testing, Child 7 required additional time to rest in between activities due to fatigue. She required two 2.5 hour sessions for each baseline, more than double the amount of time compared to the other participants. After the intervention, however, Child 7 did not require extensive rests during testing. She completed the post intervention testing in one session lasting 2.5 hours and she repeated this performance for the follow-up testing.

Table 1. Participant characteristics.

Child	GMFCS* Level	Distribution & secondary diagnosis	Age	Sex	BMI** Percentile	Maximal Heart Rate (MHR) (beats/minute)***	Training HR Range of 70–80% MHR (beats/minute)
1	I	Left hemiplegia & autism	6.3	M	25th	194	136–155
2	I	Right hemiplegia	7.1	F	97th	202	141–162
3	I	Right hemiplegia	15.2	M	37th	196	137–157
4	III	Spastic diplegia	6.5	F	1st	183	128–146
5	III	Spastic diplegia	10.4	M	72nd	196	137–157
6	III	Spastic triplegia	11.9	F	60th	203	142–162
7	III	Spastic diplegia	12.3	F	82nd	191	134–153
8	III	Spastic diplegia	14.4	M	97th	201	141–161

*Gross Motor Function Classification System.
**Body Mass Index.
***Determined using the Shuttle Run Test I for children at GMFCS Level I and SRT III for children at GMFCS Level III.

Table 2. Participant PT services, active recreation and swimming experience.

Child	School-based PT services (land setting)	Previous Outpatient PT Services (Land or aquatic setting)	Sports/Active Recreation Participation During the Study Period	Previous Swimming Experience and Swimming Skills Using the Swimming Classification Scale (Fragala-Pinkham, O'Neil, and Haley, 2010)
1	2 times/wk for 30 minutes	3 month episode of land-based outpatient PT 1x/wk, 6 months before this study started	None	• Level 1: Unable to swim a lap even with a floatation device
2	None	4 month episode of land and aquatic-based outpatient PT 2x/month, 5 months prior to participation in this study	None	• Level 3: Able to swim one or more laps with one foam piece on the floatation belt • Took swim lessons at summer camp.
3	None	6-month episode of combination of land and aquatic-based outpatient PT 1–2x/wk, 4 years prior to this study and following orthopedic surgery to right lower extremity	Participated in an adapted rowing program two times per week throughout the study period	• Level 5: Able to swim several laps without stopping and without a floatation device; working on swim stroke techniques for several strokes including backstroke, front crawl, breast stroke • Took private adapted swim lessons and learned to swim several years ago.
4	1 time/wk for 30 minutes	4 month episode of land-based outpatient PT 1x/wk, 3 months prior to participation in this study	None during the baseline and intervention phases. During the follow-up phase, started attending an after-school inclusive program at the Boys and Girls Club participating in daily sports activities and extensive walking within their building on level surfaces and stairs.	• Level 1: Unable to swim a lap even with a floatation device
5	1 time/wk for 30 minutes	6 month episode of land-based outpatient PT 1x/wk, 6 months prior to participation in this study	During the baseline and intervention, informally played soccer, basketball, and wall ball with friends most days after school. During the follow-up phase, started a 1x/wk adaptive skating program and initiated a walking training program with his family in preparation for a 1-mile school race.	• Level 5: Able to swim several laps without stopping and without a floatation device; working on swim stroke techniques for several strokes including backstroke, front crawl, breast stroke • Took swim lessons at YMCA and learned to swim several years ago.
6	None	Combination land and aquatic-based outpatient PT 1x/wk for 2 month period, 6 months prior to participation in this study	None	• Level 4: Able to swim one lap without a floatation device and without stopping • Took swim lessons at YMCA and learned to swim several years ago.

(*continued*)

Table 2. Continued

Child	School-based PT services (land setting)	Previous Outpatient PT Services (Land or aquatic setting)	Sports/Active Recreation Participation During the Study Period	Previous Swimming Experience and Swimming Skills Using the Swimming Classification Scale (Fragala-Pinkham, O'Neil, and Haley, 2010)
7	1 time/wk for 30 minutes	2 month episode of land-based outpatient PT after botulinum toxin injections, 2 months prior to participation in this study. Combination land and aquatic-based outpatient PT for 4 months, 1 year prior to participation in this study.	None	• Level 2: Able to swim one or more laps with 2 or more foam pieces on the floatation belt • Took adapted swim lessons several years ago
8	None	3 month episode of outpatient PT 1x/wk combination land and aquatic setting, 1 year prior to participation in this study	None	• Level 4: Able to swim one lap without a floatation device and without stopping • Learned to swim in a relative's pool several years ago

Parents completed the Mobility and Social Cognitive Domains of the Pediatric Evaluation of Disability Inventory – Computer Adaptive Test (PEDI-CAT) at the first testing session and this information was used to describe the sample. Parents also completed questionnaires at each of the testing sessions to document any changes in medications, PT sessions outside of the study intervention, or other activities or interventions that might have impacted testing results.

Primary outcomes

The total score from the Gross Motor Function Measure Dimensions D and E was used to measure changes in gross motor skills of standing, walking, stair climbing and running. The GMFM is a criterion-referenced test designed specifically to record changes in motor skills after PT intervention. It is a valid test with excellent test–retest reliability (Russell, Rosenbaum, Avery, and Lane, 2002; Wang and Yang, 2006).

The six-minute walk test (6MWT) was used to measure walking endurance. High test–retest reliability of the 6MWT has been established for school-aged children with CP and GMFCS Levels I–III (Thompson et al, 2008). The participant was instructed to walk as fast as possible during the 6-minute interval. A 25-meter straight course was used with cones to mark the distance. The distance walked in 6 minutes was recorded and the walking speed was calculated. Resting heart rate was recorded after a 5-minute rest before the start of the walk, and a working heart rate was recorded after 6 minutes of fast walking. Consistent verbal encouragement was provided throughout the walking trial.

Secondary outcome measures

The secondary outcomes for this study were functional strength, aerobic capacity and balance. Functional strength or muscular endurance was measured with the Brockport modified curl-up, the Brockport isometric push-up and lateral step-ups. Procedures for the Brockport modified curl-up and isometric push-up as specified in the Brockport manual (Winnick and Short, 1999) were used to document trunk and upper body muscular endurance. The lateral step-ups were used to document lower extremity muscular endurance. Good test–retest reliability (ICC = 0.91–0.96) has been demonstrated on this test for children classified at GMFCS Levels I and II, ages 7–17 years. The lateral step-ups were completed using the procedures specified in Verschuren et al. (2008) for children with GMFCS Level I including using an 8 inch (20 cm step) and no arm support. For this test, children performed as many lateral step-ups as they could in 30 seconds for each leg. The same procedure for lateral step-ups was used for children with GMFCS Level III with the following modifications: (1) a smaller step of 5 inches (13 cm) was used; and (2) the step was placed next to the wall and children placed their hands on the wall for balance while performing the step-ups. Because a lateral step-up standard testing protocol for youth classified at GMFCS Level III has not been documented in the literature, we used this modified protocol developed in our clinic setting.

Aerobic capacity was measured using the shuttle run test (SRT-I) for children classified at GMFCS Level I (Verschuren, Takken, and Ketelaar, 2006) and the shuttle run test (SRT-III) for children at GMFCS Level III (Verschuren, Bosma, and Takken, 2011). These field-based tests are fast walk/running tests with standard incremental speeds and are designed to estimate aerobic capacity in youth. These tests have been validated in children with CP and GMFCS Levels I–III (Verschuren, Bosma, and Takken, 2011; Verschuren, Takken, and Ketelaar, 2006).

The Pediatric Berg Balance Scale was used to measure changes in balance. It is a criterion referenced test that has good reliability when used with school-aged children with mild-to-moderate motor impairments (Franjoine, Gunther, and Taylor, 2003).

Aquatic PT intervention

Three pediatric physical therapists conducted the majority of the intervention sessions and three other therapists covered sessions when the primary therapists were not available due to schedule conflict or vacation. The three primary therapists had a range of 2–25 years of experience providing pediatric physical therapy intervention. In addition, all of the therapists had two or more years of experience working in an aquatic environment. All of the therapists participated in general aquatic training which included water safety, risk management and emergency procedures, infection control and hydrodynamic principles and therapeutic techniques for use in the water. The therapists also received specific training for this study including discussion of the specific aims, aquatic exercises and activities, exercise intensity and use of the Polar HR monitors. In addition, a physical therapy student recorded the specific activities, water depth and HR data at 1-minute intervals during most sessions and provided therapists with feedback regarding previous session parameters to assist therapists in progressing the interventions to be more challenging for the children.

Participants received individual intervention sessions which were held two times per week for 14 weeks. The 60-minute pool sessions consisted of a 2–5 minute warm-up, 40–45 minutes of aerobic exercise, 5–10 minutes of strength training and a 5–10 minute cool down and stretch. The 8 foot by 12 foot therapeutic Hydroworx® pool was used for all of the aquatic sessions. It has an adjustable floor (variable depths); an underwater treadmill; resistive jets with different levels of intensity; removable parallel bars; and underwater cameras with a viewing monitor. The pool temperature was generally 90 °F/32 °C but can range from 88–94 °F/31–34 °C.

Different protocols and techniques are used during aquatic PT interventions. To evaluate effectiveness across a group of participants, the focus of this study was on task-specific activities using heart rate to define exercise intensity.

The aerobic exercise component consisted of deep water walking, pool treadmill walking, step climbing, running, jumping, hopping, basketball drills (lateral shuffles, backwards running), treading water, swimming, prone kicking and other movement activities (e.g. box jumps, ski jumps) to increase heart rate into training range. All of the children started with a warm-up of walking activities and progressed to higher intensity exercise with faster-paced walking. After the warm-up, participants selected the order of activities that they preferred. Walking and running was done across the pool floor and using the pool treadmill. Children generally preferred to participate in running laps in the pool by imbedding this activity into games such as racing against the therapist to gather as many plastic pool toys as possible, shooting a basketball into a hoop at the end of each lap, playing follow the leader and making a whirlpool and then running in the opposite direction against the water resistance. Step climbing was completed at each session using 6 and 8 inch boxes. The height of the water varied depending on the needs of each child. For children who required more support for standing (i.e. children classified at GMFCS Level III), the water height was mostly at the axilla so they had better walking support with or without a bar positioned in front for support and balance. The height of the water was lowered (the pool floor was raised and in turn this lowered the water level) when a child did not require as much assistance for balance and buoyancy. Improved walking performance and decreased working heart rates were indicators that a child was ready for increased challenge, and the water level was reduced for less support. The water jets were used to provide additional resistance to challenge walking skills or balance. For ''underwater running in place'', children used a floatation belt and the water height was approximately at the axilla or slightly higher but their feet did not touch the pool floor. For most sessions, children also participated in jumping, hopping, skipping, braiding, side shuffles and backward walking. Swimming, treading water and prone kicking were done less often and for shorter periods of time when new activities were needed to motivate a child. Running sprints were used for cardiorespiratory training for Child 2, 3, 5 and 6 during the last few weeks of the intervention. These sprints consisted of running on the treadmill and then exceeding the treadmill speed and racing the therapist to the front of the pool and stepping onto the stationary section of the pool. Then the child had to quickly step back onto the moving treadmill, ride to the middle of the pool while maintaining balance and then turn around and continue the sprinting drill. Rests were individualized for each child and at the start of the program were more frequent than at the end of the 14-week program. Generally, at the beginning of the program, children were encouraged to exercise for 6–8 minutes before taking a short 2–3 minute rest standing or floating in the water. By the end of the program, most of the children were able to exercise for 15–20 minutes before taking a short rest. All tasks were carried out in the pool environment.

The intended training intensity was 70–80% of maximal heart rate as calculated using the SRT data for maximal heart rate (Verschuren, Maltais, and Takken, 2011). Refer to Table 1 for maximal heart rate and training range values for each child.

The muscular strengthening component consisted of leg and trunk movements using aquatic noodles, leg weights, fins and water resistance for 2–3 sets of 10 reps. The leg exercises were done in standing, alternating sides and included hip flexion and extension with knee flexed and with knee extended, hip abduction and adduction with knee extended, heel raises. Upper extremity exercises were also done in standing and included pushing a noodle under the water using shoulder extensors and triceps bilaterally (''lat pull down''), holding a noodle vertically and moving it clockwise and counterclockwise (''stirring the pot''), and shoulder abduction and adduction. For trunk strengthening, some children worked on sitting on a noodle and balancing with the therapist providing assistance or resistance. Others did position changes from supine float to prone float using trunk flexion and extension or ''pool crawls'' by moving around the edge of the pool using arms to hold onto the pool and toes up on the side of the pool. The cool-down component of the program consisted of slow movement activities and stretching while the participant's working heart rate returned to within baseline range. Target HR was measured with a Polar HR monitor (model RCX5) worn by participants during aquatic sessions. Time spent in, above and below target heart rate was recorded during each session as well as the number of repetitions of leg exercises and types of activities.

Statistical analysis

Multiple single factor repeated measures analysis of variance (ANOVA) were generated to compare mean scores on primary (gross motor function and walking endurance) and secondary outcomes (functional strength, balance, aerobic fitness) by time (two baseline, post intervention, follow-up). Homogeneity of variance was tested using Mauchly's test of sphericity. When the ANOVA resulted in a significant overall F-statistic, *post-hoc* tests were conducted using the Bonferroni correction to compare means and adjust the confidence intervals. Effect sizes were examined for each of the outcome variables (Ferguson, 2009).

Results

The assumptions of homogeneity of variance and equal correlations across observations were satisfied for the repeated-measures ANOVA. No significant changes were observed on any of the outcomes between the two baseline measures, indicating a stable baseline period. Significant improvements were observed for the two primary outcomes of gross motor function ($F(3,21) = 39.4$, $p \leq 0.001$) and walking endurance ($F(3,21) = 9.8$, $p \leq 0.001$) across the four measurement times (two baseline, one post intervention and one follow-up). *Post-hoc* contrasts indicated that there was no significant difference between the two baseline measures suggesting that participants were stable on these characteristics prior to the intervention. *Post-hoc* contrasts indicated significant changes from baseline to post intervention and follow-up measures, suggesting that the improvement in gross motor function and walking endurance was maintained at the one month follow-up. However, there was no significant improvement between post intervention and follow-up

Table 3. Comparison of baseline, post intervention and follow-up outcomes.

	Baseline 1 Mean (SD)	Baseline 2 Mean (SD)	Post Intervention Mean (SD)	1 Month Follow-up Mean (SD)	Post Hoc Tests (factor = test time) Bonferroni Correction Alpha Levels	Eta Square Values
Primary outcome measures						
GMFM Dimensions D & E (% score)	63.4 (8.7)	61.9 (8.4)	70.7 (8.7)	70.8 (8.8)	1 vs. 2 $p = 0.54$ (NS) 1 vs. 3 $p = 0.004$ 2 vs. 3 $p < 0.001$ 2 vs. 4 $p = 0.001$ 1 vs. 4 $p = 0.003$ 3 vs. 4 $p = 1.0$ (NS)	0.85
6 MWT (meters)	340.8 (48.4)	360.6 (48.1)	424.3 (42.5)	384.5 (36.2)	1 vs. 2 $p = 1.0$ (NS) 1 vs. 3 $p = 0.004$ 1 vs. 4 $p = 0.54$ (NS) 2 vs. 3 $p = 0.001$ 2 vs. 4 $p = 1.0$ (NS) 3 vs. 4 $p = 0.17$ (NS)	0.58
Secondary outcome measures						
SRT I and III (Levels)	6.94 (1.84)	6.94 (1.97)	9.25 (2.3)	8.63 (2.2)	NA	0.56
Pediatric Berg Balance (% score)	67.9 (8.9)	69.1 (8.8)	76.8 (7.9)	77.7 (7.9)	NA	0.55
Lateral Step-ups (repetitions)	10.3 (5.1)	10.3 (4.7)	16.6 (5.0)	16.9 (4.7)	NA	0.32
Modified Curl-ups (repetitions)	6.6 (2.2)	7.4 (2.5)	17.1 (6.6)	14.4 (4.1)	NA	0.30
Isometric Push-ups (seconds)	9.7 (7.3)	8.3 (5.3)	23.2 (6.8)	20.0 (8.3)	NA	0.40

NS – Not significant on post-hoc analysis.
NA – Not significant for the ANOVA analysis therefore post-hoc tests were not completed or significant for ANOVA but not significant for post-hoc tests.

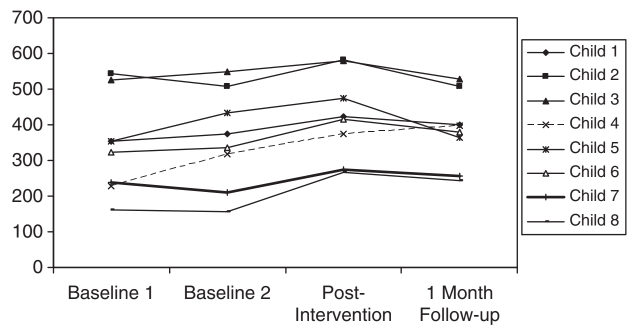

Figure 1. 6 Minute walk test (distance in meters).

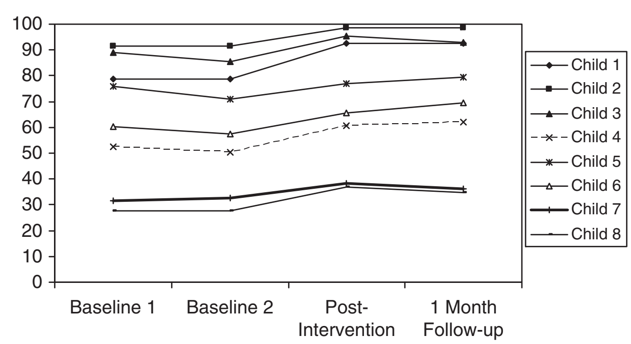

Figure 2. GMFM dimensions D & E (% scores).

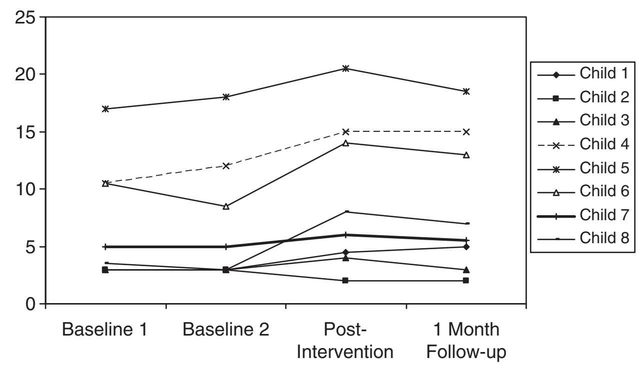

Figure 3. Shuttle run tests (levels).

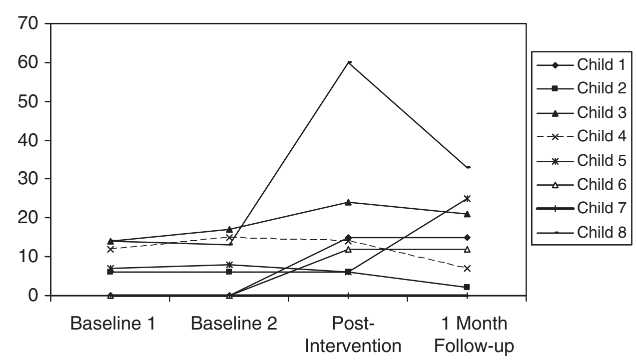

Figure 4. Modified Curl-ups (1 every 3 seconds).

measures, suggesting that improvement was maintained but did not increase in the follow-up period. Mean and standard deviation data for the two primary and five secondary outcome measures across the four measurement sessions are in Table 3. Figures 1 and 2 provide trend data on the two primary outcomes and Figures 3–7 provide trend data on the secondary outcomes.

For the five secondary outcome measures, three outcomes (Pediatric Berg Balance, modified curl-up and lateral step-ups) did not meet the assumption of sphericity so the Greenhouse-Geiser correction was used. ANOVA results were significant for the Pediatric Berg Balance Test ($F(1.43,10) = 8.64$, $p < 0.05$) but there were no significant findings on the *post-hoc* comparisons. There were no significant findings for the modified curl-up or

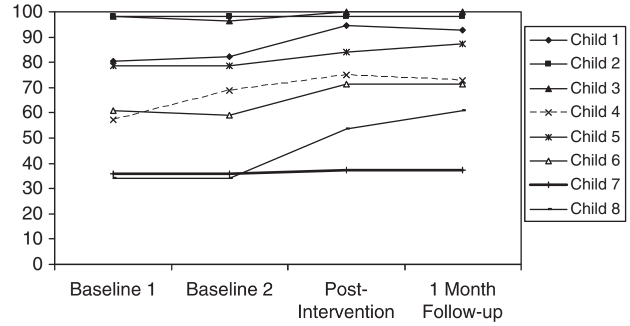

Figure 5. Pediatric berg balance (% score).

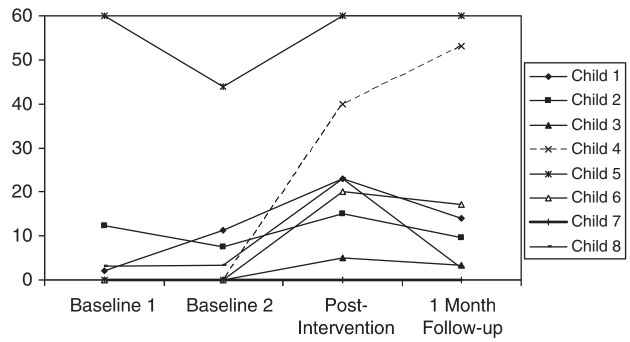

Figure 6. Isometric Pushup (seconds).

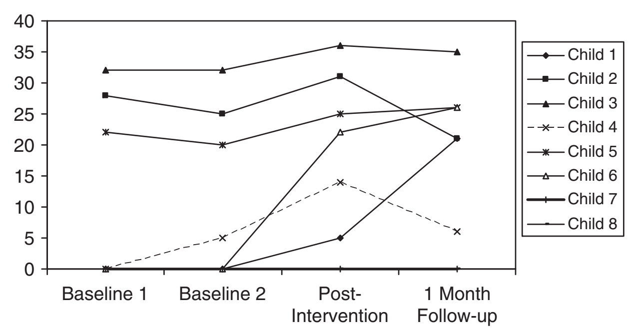

Figure 7. Combined lateral step-ups (# repetitions in 30 seconds).

lateral step-ups. ANOVA results were significant for the isometric push-up test ($F(3,21) = 4.57$, $p < 0.05$) and for aerobic capacity on the shuttle run tests ($F(3,21) = 7.52$, $p < 0.01$) but neither measure had significant findings on the Bonferroni *post-hoc* comparison tests. All secondary measures, however, demonstrated trends for improvements after the intervention and either leveled off or declined slightly at the one month follow-up.

Six out of the 8 children participated in twice per week sessions for 14 weeks and completed all 28 sessions. The other two participants had a slightly altered program frequency with one participant completing 24 sessions and one completing 26 sessions. The two children who missed 2 or 4 sessions participated in twice per week sessions for the first 18 or 20 sessions and then once per week due to change in parent work schedule and transportation issues or other scheduling conflicts with after-school activities or other medical appointments.

Target HR was calculated using the maximal heart rate established during the SRT-I and SRT-III tests at baseline. Generally the target HR range was 70–80% of maximal HR; however, if a child went above the range, we did not have them

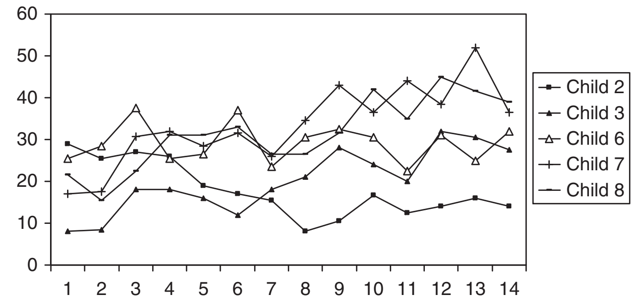

Figure 8. Aquatic training intensity.

decrease their exercise intensity if they tolerated the activity in terms of respiratory status and motor control. Consistent HR data during the program were obtained for five of the eight participants. Problems with tolerance in wearing the HR monitor for one participant and inconsistent fit with two of the participants limited heart rate data collection during portions of many sessions making it difficult to accurately estimate total time spent in THR. HR data were used to gauge the exercise intensity for all of the participants. For the two children with poor monitor fit, therapists held the strap against their chest to get a reading but this was not possible to carry out during the entire exercise bout so it was done after a few minutes of each exercise activity for a 20–30 second period to establish if the child was exercising at sufficient intensity. For the five participants in which reliable HR data were available, four exercised for $\geq$20 minutes at or above THR during the majority of their sessions (Figure 8).

Two children developed blisters from running on the pool treadmill. The blisters were initially identified by the therapists during skin inspection because the two children had decreased sensation and did not complain of discomfort. This problem was resolved completely in one child with well-fitting water shoes; the second child had difficulty with the fit of water shoes and needed a combination of waterproof bandaids and water shoes to prevent blister development. No infections or other adverse reactions were observed during this aquatic intervention.

None of the children started taking new medications during the study period. None of the children had a change in their school PT services or other active recreation during the baseline and intervention phases. Some changes were reported during the follow-up phase. During the follow-up period after the intervention, Child 4 started an after school inclusive program at the Boys and Girls Club participating in daily sports activities and Child 5 started a 1 time per week adaptive skating program and initiated a walking training program with his family in preparation for a 1 mile race at school.

Discussion

The purpose of this pilot study was to evaluate the effects of an aquatic exercise program for children with CP. Improvements in gross motor skills and walking endurance were observed for these ambulatory school-aged children with CP. This study provides preliminary evidence that a 14-week twice weekly aquatic exercise program incorporating aerobic training with functional mobility activities of walking, step climbing and gross motor skills may be effective for improving mobility skills in children with mild-to-moderate physical impairments. However, the intervention may not have been strong enough to ensure that gains would be maintained in walking distance as indicated by the outcomes on the 6MWT at one-month follow-up. It may be important to incorporate an active post-intervention health promotion program for children and families to maintain gains from the intensive aquatic exercise intervention.

Results of this study are consistent with other land and aquatic exercise intervention studies for children with CP incorporating aerobic exercise and functional task-specific activities such as walking, running, step-ups and/or jumping. Improvements in GMFM scores or walking endurance have also been observed in an 8-month land-based exercise intervention (Verschuren et al, 2007) and in two previous aquatic exercise intervention studies (Retakar, Fragala-Pinkham, and Townsend, 2009; Thorpe, Reilly, and Case, 2005).

For this study, no significant improvements were observed in any of the secondary outcome measures; however, there was a trend toward improvement for the majority of the sample. Effect sizes (eta square values) for the secondary outcomes suggest moderate to large change post intervention. Eta square values are interpreted based on baseline variability and may fluctuate among outcomes due to this variability.

Some of the ''active ingredients'' that improve effectiveness of the aquatic exercise program include the ability of the child to exercise at a high enough intensity (individually specified target HR) for a sufficient amount of time. The ability to swim well and move freely in the aquatic environment at the start of the program appeared to be an advantage for participants, making it easier for them to exercise at the specified intensity.

We did not formally measure level of enjoyment; however, for most of the participants, the aquatic environment appeared to be enjoyable which may have made it motivating and easier to sustain high intensity exercise for longer periods of time. In future studies, a questionnaire to record child factors such as enjoyment, interest and motivation for exercising in the aquatic environment and confidence of moving in the aquatic environment may provide information on additional factors which could influence outcomes. Some outcome measures to consider in future research would be the Subjective Exercise Experience Scale (Markland, Emberton, and Tallon, 1997) which is validated for typically developing youth or the Children's Assessment of Participation and Enjoyment/Preferences for Activities for Children (King et al, 2004), validated for youth with CP. In addition to being motivated to exercise, children in this study demonstrated high cognitive abilities which also may have contributed to their ability to adhere to exercises and testing procedures.

One participant, a 14-year-old classified at GMFCS Level III, wanted to know ''why are we stopping this program now (after 14 weeks) when I just started being able to run and exercise for the whole hour''? Further study is needed to determine optimal training frequency, duration and episode of intervention. This same participant reported that he could not exercise on land as long as he could exercise in water. He also reported discomfort when walking long distances on land but could run in water at axilla height for 15 minutes without taking a rest, and without pain or discomfort. Although we did not formally measure pain during exercise sessions, we did note that none of the children complained of pain during the aquatic intervention. Future study should include treadmill training or overground walking compared to walking and exercise in the water. Outcomes aimed at evaluating improvements in function along with systematic measurement of pain and discomfort should be included.

For this small pilot, we did not see any trends to suggest that age or GMFCS Level influenced response to aquatic exercise. We note that for Child 1 and Child 2 who were two of the three youngest participants, we may not have captured their best effort upon testing or during exercise sessions. All of the children classified at GMFCS Level I had CP with a hemiplegia distribution and all of the children classified at Level III had CP with a spastic diplegia distribution; however, we have no clear indication that GMFCS level impacted outcomes. We did observe that GMFCS levels were highly correlated with performance on the: GMFM D&E ($r = 0.84$, $p = 0.009$); Pediatric Berg Balance ($r = 0.77$, $p = 0.02$); 6MWT ($r = 0.72$, $p = 0.04$); and SRT ($r = 0.77$, $p = 0.04$) which are all outcomes based on functional mobility tasks. GMFCS levels were not correlated significantly with modified curl-up, isometric push-up or lateral step-ups for this pilot sample. Further research is needed to determine the relationship between these specific muscular endurance tests and functional mobility skills in children with CP.

Some of the secondary measures were not sensitive to change for all of the participants. There was a ceiling effect for children classified as GMFCS Level I on the Pediatric Berg Balance Scale. In future research, other measures of balance which are more challenging should be considered for participants with higher GMFCS levels. The opposite problem was observed for the muscular endurance outcomes. A floor effect was observed for some participants classified at GMFCS Level III on the muscular endurance outcomes of modified curl-ups, isometric push-up and the lateral step-ups. For future studies, the current measures should be modified to prevent a floor effect such as further lowering the step that is used for the lateral step-ups, using a wedge for the curl-ups, and using a forearm weight bearing position for the isometric push-ups. Scaling the size of the step to the child's height in addition to their GMFCS level may be appropriate in future studies.

We experienced some problems with HR monitors early in the study including issues with chest strap fit for the smaller children, tolerance with one younger child and technical problems with conductivity. The T31-coded chest straps worked best in the water treated with bromine and when the pool treadmill was running. However, these chest straps did not fit the smaller patients. We used the Wear-Link+ Hybrid transmitter which was a better fit for the smaller patients but was problematic with use on the pool treadmill.

One limitation of this study is that we did not have a control group; however, as an alternative, we used a baseline period in which two measurements were taken. This baseline was stable with slight improvements or declines in performance that were not statistically significant. Some random variation is anticipated due to maturation and motivation to perform the fitness tests. Another limitation of this study was the small sample size; however, this pilot study provides procedural information and preliminary data to design and power a large randomized controlled trial (RCT). If we use data from this study to determine the sample size for an RCT, we estimate needing between 18 and 41 children per group depending on the outcome measure chosen. This is a reasonable number of participants for an RCT.

Another limitation of this study is that the length of the testing sessions varied. Informally several parents reported that their children took less time to complete the battery of tests in the post-intervention session than for the two baseline testing sessions. Specifically for Child 7, it took half the amount of time to complete the outcome measures at post-intervention than during the baseline testing. Because functional endurance was a critical component of this study, the testing sessions should have been identical. Potentially, we did not capture the true improvement on some outcomes on the post-intervention and follow-up tests due to test fatigue. In future studies, the rest periods between the different outcomes being administered should be the same even if a child does not require lengthy rests.

Training intensity is a critical component of an aerobic exercise program; however, little information is available on optimal aerobic training intensity for land or aquatic-based exercise programs for children with CP. According to the American College of Sports Medicine (2010), a training intensity of 40% to 60% of maximal oxygen consumption for moderate intensity and >60% for vigorous intensity or 60–90% of age-predicted maximal HR is recommended for increasing or maintaining cardiorespiratory fitness in typically developing adults. The first issue in determining training intensity is to establish maximal HR values. Age-predicted maximal HR values using 220-age are not ideal for children with or without disabilities and whenever possible maximal HR should be determined by a progressive exercise test (Machado and Denadai, 2011; Mahon et al, 2010; Verschuren, Maltais, and Takken, 2011). Further, there are issues as to whether maximal HR using a validated progressive exercise test, such as a SRT truly provides maximal HR verses peak HR in children with neuromuscular issues. In this study, we used maximal HR as the value representing the child's maximal effort which may be limited by lower extremity strength and motor coordination issues commonly seen in children with CP.

The second issue is related to what aerobic intensity level should be used for training. For determining aerobic training intensity, there were several sources that we considered. One study on the relationship of oxygen consumption to HR during exercise for 10–17-year-old typically developing children suggests that 50–85% VO_2 peak is equivalent to 72–93% of maximal HR (Hui and Chan, 2006).

We also looked at the evidence on HR during exercise in the aquatic setting. One reference (Sova, 2000) that has been used in previous studies evaluating aquatic aerobic exercise for children with disabilities (Fragala-Pinkham, Haley, and O'Neil, 2008) suggested that HR should be adjusted by 17 beats lower for exercise in water. A second reference (Becker, 2009) suggests that for aerobic exercise a 10 beat lower difference should be used for water exercise than land exercise. A third resource, the Aquatic Exercise Association Research Committee recommended measuring resting HR standing in and out of the water and using the difference when calculating training HR (Chewning et al, 2009). Further, results from another study suggest that in adults HR at the same workload of 80% maximal oxygen consumption is lower in water than on land but that HR is the same at 40% and 60% maximal oxygen consumption for water or land exercise (Sheldahl et al, 1987). No published studies compared HR and VO_2 during exercise on land and water for children with CP. Therefore, for this article, we provided a target HR range which we tried to have participants achieve during training.

At the beginning of the study children tended to exercise in the lower end of their training HR range and by the end of the study they were training at the higher end. In future studies, routinely retesting aerobic capacity and maximal HR is recommended to ensure optimal training intensity. The field-based SRT procedure can be used as a starting point by physical therapists in the clinic setting to specify individual parameters for aerobic training intensity. In addition, in future studies it would be important to examine if child personal factors (interest in exercise and participation in active leisure), their health status (GMFCS level and BMI) and training intensity levels ultimately influence functional outcomes.

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Declaration of interest

The authors report no conflicts of interest.
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