An Aquatic Physical Therapy Program at a Pediatric Rehabilitation Hospital: A Case Series

Maria A. Fragala-Pinkham, PT, MS, Helene M. Dumas, PT, MS, Carrie A. Barlow, PT, PCS, and Amy Pasternak, PT, MS

Research Center for Children with Special Health Care Needs (M.A.F-P., H.M.D.), Franciscan Hospital for Children, Boston, Massachusetts; and Physical Therapy Department (C.A.B, A.P.) Franciscan Hospital for Children, Boston, Massachusetts

Purpose: The purpose of this case series is to describe the implementation of an aquatic physical therapy (PT) program at a pediatric hospital and to document improvements in participants' abilities after PT intervention. **Methods:** Four patients with cerebral palsy, juvenile idiopathic arthritis, or Prader-Willi syndrome participated in aquatic and land-based PT intervention. Three of the patients had orthopedic conditions which required limited weight-bearing or low-joint impact during motor activities. A wide range of outcomes were used to assess changes in participation, activity, and body function. When available, minimal detectable change and minimal important difference values were used to interpret data. **Results:** Clinically significant improvements were documented in functional mobility, walking endurance, range of motion, muscle strength, and/or pain reduction for all 4 patients. **Conclusions:** Aquatic PT used as an adjunct to land-based PT interventions may be effective in improving outcomes in patients with physical disabilities. **(Pediatr Phys Ther 2009;21:68–78)** *Key words: adolescence, aquatic therapy, arthritis/juvenile, case report, cerebral palsy, child, outcome measurement, physical therapy/methods, Prader-Willi Syndrome, weight-bearing*

INTRODUCTION

Therapeutic exercise and functional activity training "on land" are common physical therapy (PT) interventions for children with disabilities. More recently, exercise and activity training "in the water" (ie aquatic PT) are gaining popularity. The properties of the water (buoyancy, resistance, and hydrostatic pressure) can assist the therapist when working on strengthening, balance training, and functional skills training while at the same time providing a fun, motivating, and safe environment.[1] Although aquatic PT intervention has many appealing qualities, information on implementation and effectiveness of aquatic PT for children is limited.

0898-5669/109/2101-0068
Pediatric Physical Therapy

Address correspondence to: Maria A. Fragala-Pinkham, PT, MS, Research Center, Franciscan Hospital for Children, 30 Warren Street, Boston, MA 02135. E-mail: mfragala@fhfc.org
Supported by The John W. Alden Trust, The Perkin Fund, and The Millipore Foundation.

DOI: 10.1097/PEP.0b013e318196eb37

We know of 3 single case reports describing aquatic PT intervention for children and youth with Waardenburg's syndrome,[2] spinal muscular atrophy type I,[3] and Rett Syndrome.[4] Improvements in endurance, ease of ambulation and walking speed,[2] muscle strength,[3] and walking balance and behavioral responses[4] were reported. Frequency of intervention was twice per week and the duration ranged from 8 to 16 weeks for 2 cases and in the third case, frequency and duration were not specified. In all 3 of these case reports, limited information was provided about the outcome measures that were used. More recently, a case series with more rigor revealed that 7 children with cerebral palsy (CP) made improvements on the Gross Motor Function Measure and the Timed Up and Go Test after a 3 times per week aquatic exercise program lasting 10 weeks.[5] During the individualized aquatic sessions, all children performed the same exercises and activities but the number of repetitions, speed, and resistance were progressed by the physical therapist based on each child's individual performance.

In addition to case reports, a few group aquatic exercise programs have been reported and can be used to inform PT practice. A combined aquatic and land-based exercise program was effective in improving respiratory vital capacity and swimming abilities in 5-year-old to 7-year-old children with CP; however, changes in functional mobility were not measured.[6] In another study which evaluated the effects of a combined aquatic and land-based program, improvements in muscle strength and functional mobility were reported for children and adults with spinal muscular atrophy type II and III.[7] Information about the intervention, outcome measures, and analyses however, was limited, making the results difficult to interpret. More recently, a case-controlled study evaluated the effects of a collaborative physical and occupational therapy aquatic program for infants and young children in early intervention. Significant improvements in gross motor skills on the Mullen Scales of Early Learning were observed in the intervention group as compared to the control group following 24 weeks of once per week aquatic therapy.[8]

Although the potential for effectiveness of aquatic intervention appears strong, studies using aquatic PT intervention for children remain limited in number and study design. Further evidence is needed to assist therapists in designing a plan of care that includes aquatic PT and determining the appropriate intervention dosage (frequency, duration, and exercise intensity). With our aquatic therapy program in its infancy, we did not have enough information or funding to design a randomized control trial but decided to first document current practice and critically evaluate this information. The purpose of this report is to provide information about the development of an aquatic PT program in a pediatric hospital. Information about the use of aquatic PT as a procedural intervention and the use of standardized tests and measures to evaluate outcomes is presented using a series of case descriptions.

PROGRAM DESCRIPTION

Franciscan Hospital for Children (FHC) is a pediatric hospital and rehabilitation center and physical therapists provide examination and intervention services to children in all of the hospital programs including inpatient, outpatient, residential, and educational. Aquatic PT services at FHC began in May 2005. In preparation for the implementation of PT services in the aquatic environment, members of the PT department conducted a review of the literature describing aquatic therapy for children.[9] Next, a pool policy and procedure manual was developed based on the pool manufacturer's guidelines, existing hospital policies and procedures, consultation from colleagues at facilities with aquatic programs and professional resource books. The therapists participated in training that included water safety, risk management and emergency procedures, infection control and hydrodynamic principles, and therapeutic techniques for use in the water. New staff members receive a comprehensive orientation and then they must demonstrate competency in specific safety and clinical procedures.

The therapeutic pool at FHC provides an 8 foot by 12 foot treatment area. It features an adjustable floor (variable depths); an underwater treadmill; resistive jets with different levels of intensity; a hand-held massage hose; removable parallel bars; underwater cameras and viewing monitor; and a computer documentation program.

CASE DESCRIPTIONS

The majority of children (73%) who use the pool are outpatients so we highlighted 3 outpatient cases and 1 inpatient case. Refer to Table 1 for demographic information.

Examination

A full examination was completed for each of the participants and consisted of a parent/child interview to gather information about the family's goals and expectations; chart review to gather pertinent medical information; and a systems review. Several tests and measures covering a range of the World Health Organization International Classification of Function levels were administered to document abilities and progress toward goals. For reexamination purposes, several tests and measures were also administered intermittently during the episode of care to record progress toward goals. For this article, we are highlighting the primary preintervention and postintervention outcome measures described in Table 2.

Evaluation

On the basis of the data gathered during the examination process, each physical therapist made clinical judgments determining the child's classification using the PT guide to practice,[10] prognosis, and types of intervention needed. As part of the evaluation, the physical therapist determined that aquatic PT was an appropriate intervention in conjunction with other procedural interventions.

Case 1. For this child, the musculoskeletal pattern 4D [impaired joint mobility, motor function, muscle performance, and range of motion (ROM) associated with connective tissue dysfunction] was chosen. The prognosis for this child was that she had the potential to regain pain-free ambulation with a symmetrical pattern and resume age-appropriate gross motor development. The long-term goals, as set by the parents and the physical therapist included: (1) Pain-free left knee for all activities, (2) Improve left knee ROM to within normal limits, (3) Improve left quadriceps strength so the child will walk with a symmetrical, age-appropriate pattern, and go up stairs leading with the left lower extremity (LE) and down leading with the right, and (4) advance gross motor skills, such as jumping in place with symmetrical push-off and landing and riding a tricycle. The plan of care was PT for 45 to 60 minutes, 2 times per week, once aquatic-based outpatient, and once land-based through an early intervention program for a total of 6 months. Procedural interventions of left knee stretching, LE strengthening, gait training, and gross motor skills training were used. Parent instruction in a home program focused on stretching, strengthening, and facilitation of gross motor skills. The clinical decision for including water-based activities in this plan of care was that water provided a low-impact environment for joint protection. Hydrostatic pressure of the water environment had the potential to limit knee edema. This child was more

TABLE 1
Demographic Characteristics of Cases

	Case 1–Outpatient	Case 2–Outpatient	Case 3–Outpatient	Case 4–Inpatient
Gender	Female	Male	Male	Female
Age	2 yr	7 yr, 10 mo	10 yr, 11 mo	19 yr
Diagnosis	Juvenile idiopathic arthritis—left knee pain with reduced range of motion and strength	Cerebral palsy—spastic diplegia	Cerebral palsy–right hemiplegia; s/p right split anterior and posterior tibial tendon transfers, posteromedial release of the subtalar and talo-navicular joint capsules and gastrocsoleus lengthening	Prader-Willi syndrome, s/p spinal fusion L1-sacrum; history of multiple spinal surgeries and complications; obesity
Functional abilities	Independent ambulator with antalgic gait pattern. Age appropriate gross motor skills on the early intervention developmental profile (at 28 mo chronological age, gross motor skills scored at 30 mo) but decreased quality and endurance due to knee pain	GMFCS level I Independent ambulator; posterior leaf ankle foot orthosis on left and UCB insert on the right	Before surgery GMFCS level I. On initial examination used wheelchair for mobility and walked distances of 4 to 5 ft with assistance; weight bearing as tolerated with bivalved short leg cast	Before surgery, walked with a rolling walker community distances, limited by pain and muscle weakness. On admission to inpatient rehabilitation, dependent for all mobility and non-weight bearing. Two months after admission progressed to partial weight bearing upright activities in the pool. Six weeks later cleared for ambulation on land
Reason for referral to PT	Referred by early intervention physical therapist for promotion of gross motor skills and knee ROM while avoiding knee pain and joint injury	Referred by physiatrist because of increased falling and heel cord tightness	Referred by orthopedist 4 wks after foot surgery for strengthening and gait training while minimizing joint forces	Referred by orthopedist for gait training and strengthening while minimizing weight bearing forces to spine

s/p indicates status post; GMFCS, Gross Motor Function Classification System; UCB, University of California Berkeley.

motivated for her PT sessions in the water and more cooperative during pool activities. Land-based PT in the home setting focused on parent instruction for a home program and functional mobility in the home environment.

Case 2. The second child was classified in neuromuscular pattern 5C (impaired motor function and sensory integrity associated with nonprogressive disorders of the central nervous system—congenital origin or acquired in infancy or childhood). The prognosis for this child was that he had potential to improve his gross motor abilities so that he could participate in play with other children and be independent and safe ambulating at home and in the community. The specific anticipated goals for this child included: (1) ambulate up and down 2 flights of stairs while carrying something in his arms, (2) get off the floor quickly and without using his hands, (3) improve walking endurance so that he will walk further in 3 minutes with improved efficiency, (4) increase bilateral passive ankle dorsiflexion and popliteal angle ROM by 10° or more, (5) improve gait pattern so that child will not trip over toes and will have a longer step length bilaterally, (6) improve standing balance so that child is able to reach further without losing his balance, and (7) improve bilateral leg strength for child to be able to jump over a small obstacle, kick a ball, and walk further with improved efficiency and fewer gait deviations. The plan of care was for a short intense program of PT 2 times per week for 5 to 6 weeks to achieve these specific mobility goals. Procedural interventions included gait training, endurance training, gross motor skills activities, balance training, strengthening, calf and hamstring stretching, and home exercise program instruction. The clinical decision for including water-based activities in this child's plan of care was because water provided a low-impact environment while at the same time being a highly motivating environment for this child. In addition, the buoyancy of the water was helpful for working on calf muscle strengthening in standing.

Case 3. For case 3, the PT classification was determined to be 4I (impaired joint mobility, motor function, muscle performance, and ROM associated with bony or soft tissue surgery) because of the child's recent orthopedic surgery and resultant muscle weakness, ROM limitations, and limited ambulation abilities. The following long-term anticipated goals were determined by the child, parents, and therapist and included: (1) independent ambulation with increased speed to keep up with other children his age, (2) independent ambulation up and down stairs without a handrail and alternating steps, (3) able to "run" faster to play informal sports with other children, (4) able to walk "without limping" (fewer gait deviations), (5) improve trunk and LE strength to allow for attainment of functional goals and improve right hip and knee strength to 4/5 and ankle strength to 2/5, and (6) improve ankle dorsiflexion ROM to 20° and ankle eversion ROM to 15°. The PT prognosis was that this child could achieve the anticipated long-term goals with a plan of care which included gait training,

TABLE 2

Tests and Measures and Psychometric Properties

Test or Measure	Psychometric Properties (SD = Standard Deviation of Baseline Reliability Data)	MDC_{90} Values	MID (points)
Canadian Occupational Performance Measure (COPM)	Responsive to change[19] Moderate test-retest reliability- performance (ICC = 0.79; SD = 1.67); satisfaction (ICC = 0.75; SD = 1.81)[20]	Performance ± 1.8 points Satisfaction ± 2.1 points	±2[20]
Gross Motor Function Measure-66 (GMFM-66)	Face and construct validity established[21] Test-retest reliability is high (ICC = 0.99)[21] and (ICC = 0.88–0.99)[22] Interrater reliability ranged from (ICC = 0.81–0.90)[22] SD = 7.7[23]	±1.79 points	±1.58[22]
Pediatric Evaluation of Disability Inventory (PEDI) mobility functional skills (FS) and caregiver assistance (CA)	Concurrent validity with Peabody Developmental Motor Scales (r = 0.64–0.95)[24] Intrarater reliability for FS Mobility (ICC = 0.98) and for CA Mobility (ICC = 0.98)[24] Interrater reliability FS Mobility (ICC = 0.92) and CA Mobility (ICC = 0.90)[24] FS Mobility SD = 17.9[23]	FS Mobility ± 5.9 points CA Mobility NA	±8.7[25] ±11.2[25]
3-min walk and Energy Expenditure Index (EEI)	EEI has been validated for children with CP[26] High test-retest reliability values (ICC = 0.94)[27] Test-retest reliability for distance walked (ICC = 0.85; SD = 40.31)[23] Test-retest reliability for EEI (ICC = 0.96; SD = 0.33)[23]	Distance = ±36.2 m EEI = ±0.15 beats/m	NA
Observational Gait Scale (OGS)	Acceptable reliability for components: knee and foot position in mid-stance, initial foot contact and heel rise interrater reliability (weighted kappas = 0.43–0.86) and intrarater reliability (weighted kappas = 0.53–0.91)[28]	NA	NA
Functional Reach Test (FRT)	Intrarater reliability is high within a single session for children with LE spasticity (ICC = 0.94–0.98)[29] Intrarater reliability between sessions (ICC = 0.87; SEM: 3.05)[29]	± 2.6 cm	NA
Timed single limb stance	Test-retest reliability data is high for one-leg standing in children with cerebral palsy (ICC = 0.99)[30]	NA	NA
Floor to Stand (FTS)	Intrarater reliability for the FTS is high (ICC = 0.89; SD = 15.2 seconds) (S. Haley, M. Fragala-Pinkham, and H. Dumas, unpublished data, 2005)[31]	11.7 sec	NA
Manual muscle testing (MMT)	Limited reliability information; Modified Medical Research Council Scale, interrater reliability ranged from 0.67 to 0.93 for children 5–15 years with Duchenne's muscular dystrophy[32]	N/A	N/A
Isometric muscle strength: hand-held dynamometer (HHD)	High test-retest reliability for LE HHD for children with CP (ICC = 0.90–0.99)[33] Test-retest reliability for knee extensors (KE) ICC = 0.95; SD = 3.3 [23] Test-retest reliability for ankle plantarflexors (AP) ICC = 0.97; SD = 6.2[23]	KE = ±1.71 kg AP = ±2.48 kg	NA
Passive range of motion (ROM)	Moderate to high intrarater reliability for children with spastic diplegia Dorsiflexion (DF) ICC = 0.63–0.69; SD = 5.6[34] Popliteal angle (PA) ICC = 0.57–.76; SD = 6.2[34] Knee extension (KE) ICC = 0.89–0.92; SD = 2.4[34]	DF = ±8.2° PA = ±9.4° KE = ±4.5°	NA
Face, Legs, Activity, Cry and Consolability (FLACC)	Valid and responsive measure of pain in young children and also for older children with cognitive impairment[35,36] Interrater reliability Kappa 0.52 (face);0.82 (cry)[35] High test-retest reliability (r = 0.80–0.883; SD = 2.8)[36,37]	±2.25–2.9 points	NA
Numerical Pain Scale	Valid measure of pain in adolescents and adults[38,39] Moderate test-retest reliability (r = 0.64; SEM = 1.3)[39]	±3 points	NA
Juvenile Arthritis Quality of Life Questionnaire (JAQQ)	Face and content validity confirmed[40] Responsiveness established for 2–18-yrs-old children with JIA[40,41]	NA	NA

gross motor skill training, LE strengthening, electrical stimulation to right ankle dorsiflexors and evertors, stretching and soft tissue mobilization for right ankle, and instruction and routine update of the home exercise program. The estimated length of PT services was 2 times per week for 1 to 2 months and 1 time per week for 3 to 4 months for a total of 4 to 6 months. The clinical decision was made to include a combination of water and land-based interventions. Land-based therapy was needed to focus on active ankle movements using electrical stimulation and to work on progressive ambulation on level surfaces and stairs eventually without the short leg cast. Water-based intervention was chosen because of the buoyancy and limited weight-bearing forces so that this patient could work on gait training using a more symmetrical pattern with emphasis on increased right LE stance time even with weight-bearing restrictions. This patient's course of intervention was complicated by a fall at home resulting in a right femoral neck fracture and surgical pinning 2 months after foot surgery and 1 month after he started receiving outpatient PT services. One week after the surgical pinning of the right hip, this patient resumed outpatient PT and was seen for a reevaluation. At that time it was determined that an additional 2 to 3 months of PT services was needed to attain long-term goals. The clinical decision was made to continue with a combination of water and land-based interventions. Land-based therapy was needed to focus on active ankle movements using electrical stimulation and to work on ambulation on level surfaces and stairs with a device and eventually progressing to full weight-bearing gait training on land without a device. Water-based intervention was used so that this patient could continue to work on gait training without a device in the water using a symmetrical walking pattern. Ambulation in chest height water was allowed 2 weeks after the hip surgery when the incision site was sufficiently healed. In addition, this child had a pool in his backyard, enjoyed swimming activities, and requested aquatic PT services and the physical therapist felt that this would assist with motivating this child to perform optimally in therapy sessions.

Case 4. For this adolescent, the PT classification was determined to be 4I (impaired joint mobility, motor function, muscle performance, and ROM associated with bony or soft tissue surgery) because of recent spinal surgery and resultant muscle weakness and limited mobility. This adolescent's mobility prognosis was considered to be good. Positive prognostic indicators included premorbid-independent ambulation status, limited neurological symptoms post-surgery, and ROM status before and immediately after surgery. Factors that limited her progress and lengthened her PT episode of care included obesity, history of previous spinal fractures with slowed bone healing, and cognitive/behavioral impairments related to the primary diagnosis of Prader-Willi syndrome. During the initial 4 weeks of treatment, the patient had non–weight-bearing precautions for her trunk and was restricted from sitting and standing activities. A plan of care was established with treatment interventions including bed mobility training, upper extremity strengthening using free weights, trunk and LE strengthening using active exercises, and endurance training. All of these interventions were initially carried out in supine because of orthopedic restrictions. Frequency was set at 4 to 5 times per week for 30 to 45 minutes per session during this period. Once the adolescent was cleared to participate in upright standing activities in water, aquatic therapy was initiated. Frequency was increased to 1 to 2 times per day for 5 to 6 days per week for 30 to 45 minutes per session because the patient was making daily progress and appeared to be benefiting from intensive therapy. Treatment activities included sit-stand transfers, as well as active ROM exercises of all 4 extremities while in a standing position in the water. Treatment interventions in the water were chosen based on the mechanics of the spine, with the general goal of unloading the spine while strengthening all musculature. Interventions in the pool were eventually progressed to ambulation on a stable surface, then to ambulation on an unstable surface (pool treadmill). As her weight-bearing status progressed, water depth was gradually decreased, subsequently increasing the load on the patient's spine. As bone healing occurred and strength and endurance improved, standing and walking activities on land were added to her program. Initial short-term goals included achieving independence with bed mobility and repositioning, as well as independence with transfers in/out of bed to a wheelchair. Long-term goals included achieving independence with standing and ambulation household distances.

Intervention

Episodes of care ranged from 6 weeks to 8 months. Frequency and procedural interventions are provided in Table 3.

Outcomes

To determine clinically significant changes in outcomes, we report minimal detectable change (MDC) and minimal important difference (MID) values when information is available. We calculated MDC for all of the tests and measures for which we could find relevant test-retest information and baseline standard deviation data. MDC is defined as the magnitude of change over and above measurement error of 2 repeated measures at a specified confidence interval.[11] For this report, we have chosen a confidence interval of 90% which is acceptable for clinical data from individual patients.[12] MID is another way to determine the amount of change needed on a specific measure to demonstrate a clinically significant change in function as defined by the patient, family, and/or therapist.[11] Table 2 contains MDC and MID values. The outcome data for cases 1 to 4 are in Tables 4–7 and summarized below.

Case 1. Clinically significant improvements in Juvenile arthritis quality of life questionnaire scores and left knee ROM were documented for this patient at the end of the 6-month intervention period. Increased left knee extension passive ROM allowed for greater knee extension and increased weight-bearing on the left LE during gait.

TABLE 3

Physical Therapy Intervention

Frequency/Duration	Procedural Interventions	Progressions
Case 1 Pool-1×/wk for 45–60 min for 6 mo Early intervention PT services at home 1×wk for 60 min	Pool • Squat to stand in water at hip height (50% weight bearing (WB)) • Gait training on underwater treadmill, 50% WB, 0.4 mph; focus on left knee extension during terminal swing, initial contact, mid and terminal stance • Shuttle running • Jumping in place with emphasis on bilateral pushoff • Step ups with focus on leading with left leg • Walking into the jets at 50% WB with jet intensity of 30% • Active/passive ROM to left hamstrings; mother instructed in home stretching program to be done in warm tub during nightly bathing Land-outpatient visits • Tricycle riding on level, smooth surfaces – initially needed moderate assistance (Rode tricycle from PT area to pool area before and at the end of pool sessions.)	Pool • Squats- ↑ repetitions, ↓ water depth (75% WB) • Treadmill-advanced to run at 2.0–2.2 mph with symmetrical pattern • Shuttle Run- ↑ distance before stopping and ↑ speed • Jumping- ↑ repetitions, ↑ speed • Step-ups- ↑ repetitions, ↓ water depth • Walking- ↑ jet intensity to 50% Land-outpatient visits • Tricycle riding on uneven surfaces, longer distance before stopping, progressed to no assistance needed
Case 2 2×/wk for 60 min for 6 wks (Total of 8 pool sessions and 4 land sessions)	Pool • Kicking activities with 2 pound ankle weight using kick board • Toe raises and heel raises in chest deep water • Balance activities, water at chest height: 1) unilateral stance, water jets at 14%, 2) jumping, 3) hopping, 4) skipping • Gait training on treadmill focusing on initial contact with a heelstrike and knee extension during initial contact and mid stance at 1.5 – 2.2 mph for 2 min increments for total of 8 min • Running/sprinting on underwater treadmill, water at hip height • Swimming above and under water against jets • Active/passive stretching for hip flexors and adductors, hamstrings, and ankle plantarflexors at end of session Land • Treadmill training, unilateral stance games (standing on 1 leg while placing the other foot on a large bolster or ball), and obstacle courses • Karate kicking activities, relay races and kicking a soccer ball toward goal while using a ½-pound ankle cuff weight • Active/passive stretching for hip flexors and adductors, hamstrings, and ankle plantarflexors at end of session	Pool • Kicking-5 pound weight by Wk 5 • Toe / heel raises –waist to knee deep water and ↑ repetitions • Balance activities, water waist to knee deep. Unilateral stance with jet intensity progressing to 50% in waist deep water. • Treadmill walking/running,- ↑ speed and for longer periods without a rest. 2.2–3.2 mph for 4 min increments for up to 20 min. Side shuffles, braiding and backward walking on treadmill. • Swimming- ↑ jet intensity from 25%–70% • Less assistance provided for stretching Land • ↑ time and speed on treadmill; ↑ balance challenges in the obstacle course such as increased height of objects to step over or narrower balance beam • Karate kicking with 3 pound cuff weight
Case 3 2×/wk for 60 min for 2½ mo and then 1x/wk for 60 min for 5½ mo. 76% of the PT visits were pool sessions	Pool • Strength training-10 repetitions of bilateral leg exercises in standing using water resistance (hip flexion; front, back and side straight leg kicks; knee flexion with hip extended; ankle plantarflexion and dorsiflexion; wall squats; kicking in prone) • Standing balance training using resistance from the jets • Sitting on balance board and maintaining position while therapist tilts board • Gait training using pool floor and treadmill, water at chest height and focusing on gait pattern-longer step length on left, increased stance time on right, initial contact with heel bilaterally • Cardiorespiratory endurance activities-treadmill walking, 0.8−1.5 mph for 1–2 min increments for 6 min total • Swimming with floatation device, cues to use right UE and LE Land • Active movement and strengthening of right plantarflexor, dorsiflexor, and evertor muscles using electrical stimulation in sitting • Progressive resistive exercises (PREs) for lower extremities bilaterally-10 repetition maximum resistance; 1 set of 10 repetitions • Trunk strengthening using a therapeutic ball and floor exercises • Gait training on level surfaces and stairs using a platform walker, uneven terrain, and stairs, balance training • Home exercise program instruction of stretching, use of short leg night cast to maintain passive range of motion, and PREs (hip extensors, abductors, quads, hamstrings)	Pool • Strength training- ↑ repetitions (2–3 sets of 15 repetitions); ↑ resistance (2–5 lb ankle weights) • Standing balance activities-added unilateral stance activities; ↑ jets to 50% • Balance board activities to increase balance reaction speed and trunk strength in sitting and kneeling • Gait training on treadmill with water waist height with fewer verbal cues; ↑ treadmill speed for fast walking and running (2.2–4.2 mph); ↑ walking speed and time to 15–22 min without rest • Step ups on 4 and 8 inch steps; ↑ repetitions; ↓ water height • Swimming without floatation against jet resistance; fewer cues to get right arm out of water and kick right leg Land • Electrical stimulation right plantarflexor, dorsiflexor, and evertor muscles during gait • PREs- ↑ 2–3 sets of 10 repetitions; ↑ amount of weight • Therapeutic exercises ↑ difficulty, repetitions, and time of exercise without rest • Gait training on stairs and uneven surfaces; running activities • Update home exercise program

(*Continued*)

TABLE 3
(*Continued*)

Frequency/Duration	Procedural Interventions	Progressions
Case 4		
Pool – 1×/day, 5 days/wk for 45 min beginning 1.5 mo into hospital stay Land – 1×/day, 6 days/wk for 45 min beginning 2.5 mo into hospital stay. Total time inpatient rehabilitation-18 wk	<u>Pool</u> ● Static stance with bilateral upper extremity (UE) support and water chest deep (25% WB) ● Sit to stand activities using pool wheelchair for consecutive repetitions without UE support ● Step-ups leading with alternating legs in parallel bars (using 3 inch high step) with WB 25% <u>Land</u> ● Squat-pivot transfers from bed → wheelchair → mat with partial weight bearing through lower extremities (25%) ● Static stance with standard walker or in parallel bars ● Closed-chain strengthening exercise via functional transfers (sit-stand, standing partial squats) ● Ambulation in parallel bars	<u>Pool</u> ● Standing-static and dynamic standing activities without UE support; ↓ level of assistive device for progression ambulation (parallel bars → walker → no assistive device) ● ↓ amount of UE support for step-ups, and advance to functional stair climbing <u>Land</u> ● ↑ level of difficulty of transfers (squat pivot → stand-pivot with UE support (walker) → stand-pivot with 2 hands held assistance) ● ↓ amount of UE support and move from static to dynamic standing tasks ● ↓ UE support (ambulation with rolling walker → ambulation with 2 hands held → independent ambulation) ● Ambulation on stairs with rail and assistance

TABLE 4
Outcome Data for Case 1

Measures	Initial	Discharge
JAQQ—gross motor		
Raw score	27	17
Mean score	3	1.2
FLACC pain scale		
Moderate activity	4/10	0/10*
4 hrs after moderate activity	2/10	0/10
MMT		
Left knee extensors	4	4
Right knee extensors	5	5
Passive ROM		
Left knee extension	−20°	−7°*

*Value greater than MDC.

TABLE 5
Outcome Data Case 2

Measures	Initial	Discharge
COPM		
Performance	1.3	7.7*†
Satisfaction	3	8*†
GMFM-66 (scaled score)	69.22	76.75*†
OGS	L 6/22 R 8/22	L 10/22 R 13/22
3-min fast walk		
EEI (beats/min)	1.02	0.85*
Distance (m)	274.3	327.36*
Standing functional reach (cm)	23	29.5*
Peak isometric strength (kg)		
Knee extensors	L 14.8 R 14.0	L 16.6* R 16.2*
Ankle dorsiflexors	L 2.2 R 2.2	L 3.3 R 3.6
Ankle plantarflexors	L 13.5 R 14.3	L 17.3* R 16.2
Passive ROM		
Popliteal angle	L 54° R 48°	L 40°* R 35°*
Ankle DF	L −5° R 5°	L 6°* R 10°

*Value greater than MDC.
†Value greater than MID.

Improved left knee extensor strength and left knee ROM appeared to positively influence her dynamic standing balance and gross motor skills. She continued to master age-appropriate motor skills, such as climbing stairs using a reciprocal pattern, running with a symmetrical pattern, jumping in place, and riding a tricycle. Pain did not increase during this episode of care even though activity level did increase. Of a possible 24 weekly sessions, this child had 6 planned absences due to family vacations and one unexpected cancellation for an attendance record of 71%.

Case 2. During this short-term 6-week intensive PT program, this patient made clinically significant improvements in gross motor function, balance, LE ROM, and on 2 strength measures. On the Canadian Occupational Performance Measure, his parents reported improvements on the following goals: (1) walk up and down stairs while carrying something in his arms, (2) run faster without falling, and (3) get off the floor with less effort and without using his arms. For the 3-minute fast walk test, this patient walked further and had a lower energy expenditure index after the intervention. Program attendance for this child was 100%.

Case 3. This patient's course of intervention was complicated by a fall and resultant right femoral neck fracture and surgical pinning. His right LE weight-bearing status regressed from weight-bearing as tolerated with short leg cast to non–weight-bearing. Regardless of the weight-bearing restrictions on land, he continued with gait training activities in the pool, as cleared by his orthopedist. At discharge from PT services, this child made clinically significant improvements on the Pediatric Evaluation of Disability Inventory, Floor to Stand, passive ankle ROM, and 3-minute fast walk. His parents also reported improvements on all of the Canadian Occupational Performance Measure goals. They suggested that his progress with walking skills was faster because he was able to practice walking in the pool even though he could not walk on land due to difficulty adhering to the weight-bearing precautions while his right hip

TABLE 6

Outcome Data Case 3

Measures	Initial	Week 5: Reexamination After Hip Fracture	Week 20: Reexamination Progressed to Full WB	Right 3 Sec
COPM				
Performance	1	NT	4.5	6.25*†
Satisfaction	1		6.25	7.75*†
PEDI mobility functional skills scaled score	38.2	20.9	85.2*†	94.2*†
Floor to stand	Needed assistance to get off the floor	Unable	5 mo: 23 sec	10.1 sec*
3-min fast walk				
EEI (beats/min)	1.77	Unable	0.93	0.66*
Distance (m)	128		253	458*
Timed single limb stance				
MMT right				
Hip abductors	3−	2−	3	4−
Hip extensors	3−	2−	3−	4−
Knee extensors	4−	≥3	4	4†
Ankle dorsiflexors	0	0	0	1
Ankle plantarflexors	0	0	1	1
Ankle invertors	0	0	0	1
Ankle evertors	0	0	0	0
Passive ROM				
Right ankle DF	5°	5°	12°	20°*
Ankle eversion	5°	5°	3°	10°*

*Value greater than MDC.
†Value greater than MID.

TABLE 7

Outcome Data Case 4

	Week 1	Week 9	Discharge
PEDI mobility FS scaled score	0	41.4	65*†
PEDI mobility CA scaled score	0	47.2	66.7*†
Walking endurance	Unable to walk on land	Walked 40 feet in pool in shoulder deep water (25% WB)	Walked in pool (25% WB) at 1.2 mph for 25 min (0.49 miles) Ambulated on land for 20 min for 350 ft × 2 repetitions with rolling walker (0.13 miles) Ambulated on land without walker with contact guard × 700 ft. in 20 min (0.13 miles)
Numerical Pain Scale	Passive and active movement: 5/10	Ambulation in pool: low back 2/10; left LE 0/10	Passive and active movement: 0/10* Ambulation land and pool: 0/10
Timed single limb stance	Not tested secondary to orthopedic restrictions	L = 0 sec R = 0 sec Unable even with assistance	L = 1 sec with 2 hands held assistance R = 3 sec with 2 hands held assistance
MMT			
Hip abductors	L 1 R 3†	L 2 R 3†	L 3 − R 4
Hip extensors	L 1 R 3	L 2 R 3†	L 2 R 3†
Knee extensors	L 2 R 3	L 3 R 3†	L 3 − R 4
Ankle dorsiflexors	L 3 R 3	L 3 R 3†	L 5 R 5
Ankle plantarflexors	L ≥3 R ≥3	L ≥3 R ≥3	L 3 R 4

*Value greater than MDC.
†Value greater than MID.

fracture was healing. Program attendance for this child was 72% over the 8-month episode of care with over half of the cancelled appointments due to other medical appointments. Other cancellations were due to vacations or illnesses.

Case 4. For the first 8 weeks, this adolescent had orthopedic restrictions which limited her participation in PT to active and passive arm and leg exercises in bed. Beginning at week 9, she was progressed to partial weight-bearing activities in the pool, but not on land. By week 12, she was able to begin brief, weight-bearing on land via stand-pivot transfers, and by week 14 she was able to initiate upright ambulation on land. At discharge, this patient was independent with household ambulation, and required close supervision for ambulation within the community. She was able to ambulate indoors without the use of her walker, and used the walker for community distances. In addition to the above clinically significant improvements in functional mobility, she was also more cooperative and independent in initiating self-movement. She improved her walking endurance, LE strength, and was pain free by discharge from inpatient rehabilitation. Program attendance for this adolescent was 100%.

DISCUSSION

The 4 cases presented in this article provide an illustration of combined land-based and water-based PT intervention where 50% or more of the PT sessions were conducted in the pool. All 4 patients demonstrated improvements in impairment level measures such as ROM, strength, balance, or pain reduction as well as improvements in functional mobility or motor skills. Though the ages, diagnoses, and goals differed for each case, the physical therapists believed that a combination of land-based and water-based intervention would assist with carryover of functional mobility skills on land. The results of these reports support previous case reports and other studies indicating that children with restrictions in activity limitations as well as impairments may benefit from aquatic PT intervention.

Across these 4 cases, the use of the underwater treadmill for promoting endurance, improved gait pattern and functional skills appeared to be a successful intervention activity. Improvements in walking speed, distance walked or functional skills have been reported for children with CP who participated in partial weight treadmill training on land.[13–15] Land-based strengthening exercises have also been shown to be effective in improving strength and function in children with CP, Prader-Willi syndrome, and Juvenile idiopathic arthritis.[16–18] For these 4 cases, active exercises with resistance of cuff weights and/or water were used to promote LE strength. Findings from other studies indicate that using aquatic resistive exercise can improve strength in children with CP.[5]

Balance activities with water at varying water depths can be used to work on balance especially for children who are fearful about losing their balance. Success performing challenging balance tasks and gross motor skills in the water can potentially increase confidence and lead to less resistance, to try difficult tasks on land. An example of this, is case 3, who was initially hesitant to walk on land for fear of foot pain but was able to walk longer distances and run in the water much sooner than on land. During walking and running activities, the buoyancy of the water reduced LE weight-bearing forces and it also helped us to determine that difficulty with running was due to impaired strength and balance and not deficits in motor control and coordination.

Program attendance was high for all 4 children. This is consistent with what PT staff anecdotally report; the number of missed appointments (cancellations or "no shows") is reduced when a child's PT program includes aquatic intervention. In addition, therapy staff members report a high degree of motivation from the children and youth treated in the water and a decline in behavior-related obstacles to accomplishing therapeutic activities.

For these 4 cases, physical therapists used a wide variety of valid and reliable measures encompassing the multiple levels of functioning depending on the individualized needs of the child. Upon review of the cases, we acknowledge that other measures could have been used to strengthen the documentation and reporting of outcomes. At present, we do not have a standard battery of tests to assess impairment, activity, and participation level outcomes and therefore it makes it difficult to directly compare and contrast the efficacy of different interventions. Although we feel that it is important for therapists to use their clinical judgment and determine what important outcomes are for each child, a general battery of tests may be helpful to guide clinical practice, particularly in a new program. In addition, as more information becomes available on psychometric properties of tests and measures, the use of MDC and MID to evaluate the outcomes on a program wide basis or for individual patients will become feasible.

For the 4 cases presented, PT examination components were not altered even if part of the intervention was anticipated to occur in the water. Examinations were individualized and a combination of participation, activity, and impairment measures were used. Therapeutic activities including strengthening, balance training, cardiorespiratory endurance training, and gait training were still the primary procedural interventions that were used during aquatic PT sessions.

A limitation of this case series is that all 4 patients received both land-based and aquatic-based PT interventions; therefore, improvements in impairment, activity, and participation level measures may be a result of interventions which were land-based, water-based, or a combination of both. Further research is needed to compare the effects of these interventions in order to definitively tease out which improvements can be attributed to aquatic PT.

After reviewing these cases, several questions have surfaced that we would like to evaluate further. Can children with CP and other disabilities improve walking endurance and exercise capacity after participating in an aquatic aerobic exercise program? Do children and families have higher levels of satisfaction and increased motivation to participate in aquatic PT than land-based PT? Do children gain mobility skills, endurance, and strength sooner after orthopedic surgeries if they participate in aquatic PT intervention soon after surgery while they have limitations in weight-bearing? It would also be helpful to evaluate the long-term effects on joints of exercising in the low-impact environment of water rather than the higher impact forces on land. As a result of this work, several additional projects were initiated including the evaluation of aquatic PT using a single subject ABA design and a group aquatic exercise program using a quasi-experimental design in a community pool.

Since the initiation of aquatic therapy services in 2005, the response from referral sources, children and families, and therapy staff has been positive. To date, there have been no reported injuries or safety incidents. The pool is used by physical and occupational therapists with patients in all hospital programs but outpatient aquatic PT referrals are the highest and continue to increase. Minor logistical problems have been encountered. The demand for aquatic therapy appointments is high and has generated some scheduling conflicts, which have been resolved by extending appointment times into the evening hours. Therapists have noted that documenting patient response to treatment during the session is challenging.

CONCLUSION

An aquatic PT program has been a successful addition to a pediatric rehabilitation hospital PT program. On the basis of the 4 cases, we have presented aquatic PT programs in conjunction with land-based PT intervention may help to improve participation, activity, and body function in young patients with varying types of physical disabilities. Further research is needed to determine the effectiveness of individual aquatic PT interventions for young patients with disabilities.

ACKNOWLEDGMENTS

The authors thank the children and their families for participating.

REFERENCES

1. Kelly M, Darrah J. Aquatic exercise for children with cerebral palsy. *Dev Med Child Neurol.* 2005;47:838–842.
2. Duvall R, Roberts P. Aquatic exercise therapy: the effects on an adolescent with Waardenburg's syndrome. *Phys Ther Case Rep.* 1999;2:77–82.
3. Figuers C. Aquatic therapy intervention for a child diagnosed with spinal muscular atrophy. *Phys Ther Case Rep.* 1999;2:109–112.
4. Bumin G, Uyanik M, Yilmaz I, et al. Hydrotherapy for Rhett syndrome. *J Rehabil Med.* 2003;35:44–45.
5. Thorpe D, Reilly M, Case L. The effects of an aquatic resistive exercise program on ambulatory children with cerebral palsy. *J Aquat Phys Ther.* 2005;13:21–34.
6. Hutzler Y, Chacham A, Bergman U, et al. Effects of a movement and swimming program on vital capacity and water orientation skills of children with cerebral palsy. *Dev Med Child Neurol.* 1998;40:179–181.
7. Cuhna M, Oliviera A, Labronici R, et al. Spinal muscular atrophy type II (intermediary) and III (Kugelberg-Welander): evolution of 50 patients with physiotherapy and hydrotherapy in a swimming pool. *Arq Neuropsiquiatr.* 1996;54:402–406.
8. McManus B, Kotelchuck M. The effect of aquatic therapy on functional mobility of infants and toddlers in early intervention. *Pediatr Phys Ther.* 2007;19:275–282.
9. Dumas H, Francesconi S. Aquatic therapy in pediatrics: annotated bibliography. *Phys Occup Ther Pediatr.* 2001;20:63–78.
10. *Guide to Physical Therapist Practice.* 2nd Ed. Alexandria, VA: American Physical Therapy Association; 2001.
11. Haley S, Fragala-Pinkham M. Interpreting change scores of tests and measures used in physical therapy. *Phys Ther.* 2006;86:735–743.
12. Schmitt J, Di Fabio R. Reliable change and minimum important difference (MID) proportions facilitated group responsiveness comparisons using individual threshold criteria. *J Clin Epidemiol.* 2004;57:1008–1018.
13. Provost B, Dieruf K, Burtner P, et al. Endurance and gait in children with cerebral palsy after intensive body-weight supported treadmill training. *Pediatr Phys Ther.* 2007;19:2–10.
14. Begnoche D, Pitetti K. Effects of traditional treatment and partial weight treadmill training on the motor skills of children with spastic cerebral palsy. *Pediatr Phys Ther.* 2007;19:11–19.
15. Dodd K, Foley S. Partial body-weight-supported treadmill training can improve walking in children with cerebral palsy: a clinical controlled trial. *Dev Med Child Neurol.* 2007;49:101–105.
16. Dodd K, Taylor N, Damiano D. A systematic review of the effectiveness of strength-training programs for people with cerebral palsy. *Arch Phys Med Rehabil.* 2002;83:1157–1164.
17. Schlumpf M, Eiholzer U, Gyrax M, et al. A daily comprehensive muscle training programme increases lean mass and spontaneous activity in children with Prader-Willi Syndrome after 6 months. *J Pediatr Endocrinol Metab.* 2006;19:65–74.
18. Singh-Grewal D, Schneiderman-Walker J, Wright V, et al. The effects of vigorous exercise training on physical function in children with arthritis: a randomized, controlled, single-blinded trial. *Arthritis Care Res.* 2007;57:1202–1210.
19. Law M, Polatajko H, Pollock N, et al. Pilot testing of the Canadian Occupational Performance Measure: clinical and measurement issues. *Can J Occup Ther.* 1994;61:191–197.
20. Law M, Baptiste S, Carswell A, et al. *Canadian Occupational Performance Measure.* 3rd ed. Ottawa, Canada: CAOT Publications ACE; 1998.
21. Russell D, Avery L, Rosenbaum P, et al. Improved scaling of the gross motor function measure for children with cerebral palsy: evidence of reliability and validity. *Phys Ther.* 2000;80:873–885.
22. Wang H, Yang Y. Evaluating the responsiveness of 2 versions of the gross motor function measure for children with cerebral palsy. *Arch Phys Med Rehabil.* 2006;87:51–56.
23. Fragala-Pinkham M, Haley S, Rabin J, et al. Case report: a fitness program for children with disabilities. *Phys Ther.* 2005;85:1182–1200.
24. Nichols D, Case-Smith J. Reliability and validity of the Pediatric Evaluation of Disability Inventory. *Pediatr Phys Ther.* 1996;8:15–24.
25. Iyer L, Haley S, Watkins M, et al. Establishing minimal clinically important differences for scores of the pediatric evaluation of disability inventory for inpatient rehabilitation. *Phys Ther.* 2003;83:888–898.
26. Rose J, Gamble J, Burgos A, et al. Energy expenditure index of walking for normal children and for children with cerebral palsy. *Dev Med Child Neurol.* 1990;32:333–340.
27. Wiart L, Darrah J. Test-retest reliability of the energy expenditure index in adolescents with cerebral palsy. *Dev Med Child Neurol.* 1999;41:716–718.
28. Mackey A, Lobb G, Walt S, et al. Reliability and validity of the Observational Gait Scale in children with spastic diplegia. *Dev Med Child Neurol.* 2003;45:4–11.
29. Niznik T, Turner D, Worrell T. Functional reach as a measurement of balance for children with lower extremity spasticity. *Phys Occup Ther Pediatr.* 1995;15:1–15.
30. Liao H, Mao P, Hwang A. Test-retest reliability of balance tests in children with cerebral palsy. *Dev Med Child Neurol.* 2001;43:180–186.
31. Haley S, Fragala-Pinkham M, Dumas H. A physical performance measure for individuals with mucopolysaccharidosis type I. *Dev Med Child Neurol.* 2006;48:576–581.
32. Florence J, Pandya S, King W, et al. Intrarater reliability of manual muscle test (Medical Research Council Scale) grades in Duchenne's muscular dystrophy. *Phys Ther.* 1992;72:115–126.
33. Crompton J, Galea M, Phillips B. Hand-held dynamometry for muscle strength measurement in children with cerebral palsy. *Dev Med Child Neurol.* 2007;49:106–111.
34. Kilgour G, McNair P, Stott N. Intrarater reliability of lower limb sagittal range-of-motion measures in children with spastic displegia. *Dev Med Child Neurol.* 2003;45:391–399.
35. Merkel S, Voepel-Lewis T, Shayevitz J, et al. The FLACC: a behavioral scale for scoring postoperative pain in young children. *Pediatr Nurs.* 1997;23:293–297.

36. Voepel-Lewis T, Merkel S, Tait A, et al. The reliability and validity of the face, legs, activity, cry consolability observational tool as a measure of pain in children with cognitive impairment. *Anesth Analg.* 2002;95:1224–1229.
37. Voepel-Lewis T, Malviya S, Tait A. Validity of parent ratings as proxy measures of pain in children with cognitive impairment. *Pain Manag Nurs.* 2005;6:168–174.
38. Gagliese L, Weizblit N, Ellis W, et al. The measurement of postoperative pain: a comparison of intensity scales in younger and older surgical patients. *Pain.* 2005;117:412–420.
39. Stratford P, Spadoni G. The reliability, consistency, and clinical application of a numeric pain rating scale. *Physiother Can.* 2001;53: 88–91.
40. Duffy C, Tucker L, Burgos-Vargas R. Update on functional assessment tools. *J Rheumatol.* 2000;27(suppl 58):11–14.
41. Duffy C, Arsenault L, Duffy K, et al. The Juvenile Arthritis Quality of Life Questionnaire—development of a new responsive index for juvenile rheumatoid arthritis and juvenile spondyloarthritides. *J Rheumatol.* 1997;24:738–746.