

Pediatric Aquatic Therapy on Motor Function and Enjoyment in Children Diagnosed With Cerebral Palsy of Various Motor Severities

Journal of Child Neurology
2015, Vol. 30(2) 200-208
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DOI: 10.1177/0883073814535491
jcn.sagepub.com


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Abstract

This study investigates the effects of pediatric aquatic therapy on motor function, enjoyment, activities of daily living, and health-related quality of life for children with spastic cerebral palsy of various motor severities. Children with spastic cerebral palsy were assigned to a pediatric aquatic therapy group ($n = 11$; mean age = 85.0 ± 33.1 months; male : female = 4 : 7) or a control group ($n = 13$; mean age = 87.6 ± 34.0 months; male : female = 9 : 4). The statistic results indicate that the pediatric aquatic therapy group had greater average 66-item Gross Motor Function Measure following intervention than the control group ($\eta^2 = 0.308$, $P = .007$), even for children with Gross Motor Function Classification System level IV (5.0 vs 1.3). The pediatric aquatic therapy group had higher Physical Activity Enjoyment Scale scores than the control group at post-treatment ($P = .015$). These findings demonstrate that pediatric aquatic therapy can be an effective and alternative therapy for children with cerebral palsy even with poor Gross Motor Function Classification System level.

Keywords

aquatic therapy, spastic type cerebral palsy, pool therapy

Received January 01, 2014. Received revised March 20, 2014. Accepted for publication April 17, 2014.

Cerebral palsy, the most common childhood physical disability, describes a group of nonprogressive disorders of the premature developing brain that adversely affect movement and posture, causing limitations in activities and participation. Additionally, cerebral palsy is frequently accompanied by sensation, perception, cognition, communication, and secondary musculoskeletal problems.¹ Motor dysfunctions in children with cerebral palsy result in limited activities of daily living and low participation in leisure activities, adversely affecting these children's enjoyment and quality of life.²

Many studies have pointed to the potential of pediatric aquatic therapy programs to significantly benefit children with cerebral palsy.^{3,4} Aquatic therapy has physiological effects that can be classified into thermal and mechanical effects. Mechanical effects include both hydrostatic and hydrodynamic effects.⁵ The mechanical effects of aquatic therapy include buoyancy, hydrostatic pressure, and hydrodynamic force. Buoyancy decreases the effect of gravity and enables children with cerebral palsy perform activities they cannot perform on land. For example, children with cerebral palsy in Gross Motor Functional Classification Level IV have difficulty walking on

land and participate less in playground activities, but they engage in more physically active play with peers in a water environment. Hydrostatic pressure assists in muscle training,

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and hydrodynamic forces facilitate balance and posture training. Thermal effects can increase soft-tissue elasticity, reduce pain, and decrease spasticity in children with cerebral palsy.⁵ Exercise in water decreases the influence of gravity, increases postural support, reduces joint loading and impact, and improves aerobic and muscular strength for children with cerebral palsy.³ These benefits make aquatic therapy a desirable environment for children with cerebral palsy.³⁻⁸ However, muscle weakness, poor joint alignment, and muscle contracture in children with cerebral palsy leads to pain and fatigue, causing problems in engagement and compliance in conventional land-based therapy.⁹⁻¹¹ Aquatic therapy protects joint integrity more than land-based exercises¹² and has proved useful in improving gross motor function,^{3,4} reducing spasticity, increasing cardiorespiratory endurance^{13,14} and vital capacity, and improving gait in children with cerebral palsy.^{3,8}

In children diagnosed with cerebral palsy at Gross Motor Functional Classification System Levels IV and V, land-based activities are more difficult than for those at Gross Motor Functional Classification System Levels I and II.⁴ Physical factors, and personal and environmental barriers may play a role in these difficulties for children with Motor Functional Classification System Levels IV and V. Therefore, children at Motor Functional Classification System Levels IV and V typically show only slight improvement after land-based therapy. Planning treatment strategies for children with severe cerebral palsy is extremely challenging for clinicians. Aquatic therapy is likely very beneficial for cerebral palsy children at Motor Functional Classification System level IV and V.⁴ However, most studies focused on pediatric aquatic therapy for high-functioning children and adolescents with cerebral palsy, that is, populations of ambulatory children and adolescents (diplegia and hemiplegia; Gross Motor Functional Classification System levels I, II, and III).^{3,4,6-8} To date, the benefits of pediatric aquatic therapy for children with cerebral palsy at Gross Motor Functional Classification System level IV and V remain unknown. This study applies the pediatric aquatic therapy to children with cerebral palsy with different motor function severities, including those at Gross Motor Functional Classification System level IV.

Rehabilitation strategies for children focus on both physical and emotional needs, incorporating engagement and enjoyment as key aspects of pediatric rehabilitation programs.¹⁵ Characterizing pediatric aquatic therapy as a therapeutic success is limited by whether improvements in motor function and enjoyment can be transferred to improved participation in activities of daily living and health-related quality of life. Thus, this study investigates whether pediatric aquatic therapy improves motor function, enjoyment, participation in daily activities, and health-related quality of life for children with spastic cerebral palsy. Furthermore, the motor function improvement associated with cerebral palsy subtypes and Gross Motor Functional Classification System levels are identified. Primary outcomes were assessed using the Modified Ashworth Scale, 66-item Gross Motor Function Measure, and Physical Activity Enjoyment Scale. Secondary outcomes were assessed using the Vineland

Adaptive Behavior Scale, and Cerebral Palsy Quality-of-Life-parent proxy scale. We hypothesize that pediatric aquatic therapy can improve motor function, reduce spasticity, and increase enjoyment for children with cerebral palsy, further enhancing their participation in activities of daily living and their health-related quality of life.

Materials and Methods

Participants

Children with spastic cerebral palsy were recruited from the Department of Physical Medicine and Rehabilitation at 2 tertiary hospitals. Inclusion criteria were as follows: diagnosis of spastic cerebral palsy; age of 4 to 12 years; Gross Motor Function Classification System levels of I to IV¹⁶; and ability to follow instructions. Exclusion criteria were as follows: receiving botulinum toxin injections or surgery no earlier than 6 months before project start; a psychiatric disorder or communication disorder such as autism or mental retardation; poorly controlled epilepsy; skin problems such as open wounds; or active infection. The Institutional Review Board for Human Studies at Chang Gung Memorial Hospital approved the study protocol. Participants and their parents or guardians provided informed consent.

Design and Procedure

This single-blind, quasi-experimental prospective study used Consolidated Standards of Reporting Trials agreement guidelines (Figure 1). A “quasi-experimental” study is an empirical study that estimates the causal effect of an intervention on a target population. This type of study lacks randomized assignment to treatment or control groups. Thus, this study is defined as quasi-experimental because it lacks randomization. Among the 46 eligible candidates, only 24 children completed the study. Nineteen children withdrew from the study at enrolment. The reasons were participation in other studies ($n = 8$), tight family schedules ($n = 5$), and no willingness ($n = 6$). After the study began, 3 children were lost: 1 because of another family schedule, 1 because of a transport problem, and 1 because of botulinum toxin injection treatment. The remaining 24 participants were classified into the pediatric aquatic therapy group ($n = 11$) or the control (conventional therapy) group ($n = 13$) according to their preferences (Figure 1). Children in the pediatric aquatic therapy group participated in a 12-week pediatric aquatic therapy program for 1 hour twice weekly in addition to conventional therapy. The children in the control group continued their original conventional therapies. Except for the Physical Activity Enjoyment Scale, all participants underwent a series of assessments of primary and secondary outcome measures before and after the 12-week intervention within 1 week. The Physical Activity Enjoyment Scale was later used to measure enjoyment after intervention. The Physical Activity Enjoyment Scale has been validated in elementary school children but lacks experience in children with cerebral palsy.¹⁷

The Gross Motor Function Classification System levels and cerebral palsy subtypes of all participants were determined by the same physiatrist (C L Chen). The Modified Ashworth Scale¹⁸ and 66-item Gross Motor Function Measure were applied by 3 physical therapists with 1 to 4 years of clinical experience and blind to group allocation. The one-on-one pediatric aquatic therapy was implemented by 1 certified physical therapist who had over 10 years of pediatric aquatic therapy experience and familiarity with human neurodevelopment and the biomechanics of aquatic therapy.

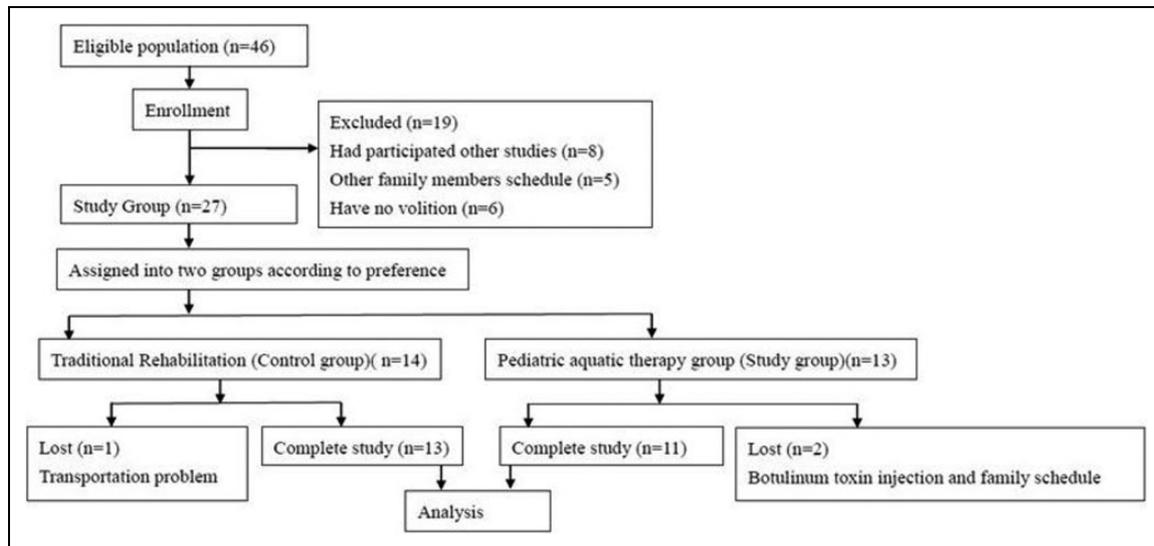


Figure 1. Study flowchart.

Conventional Rehabilitation Programs

Conventional therapy is defined as the therapy in which the children were participating prior to the study. Conventional therapy comprised land-based rehabilitation programs and focused on basic mobility skills, such as standing, walking, climbing stairs, and reaching or operating a wheelchair.¹⁹ These exercises included stretching, strength training, fitness training, management of spasticity, and using assistive adaptive equipment.^{19,20} These training programs were based on neurodevelopment, sensory integration, or the Bobath theorem.⁶ The average frequency and duration of conventional therapy of both groups are presented in Table 1. The conventional programs varied among the participants; however, most children had received physical rehabilitation and occupational therapy in 30-minute sessions 2 to 3 times per week.

Pediatric Aquatic Therapy Intervention

The pediatric aquatic therapy program comprised 5 to 10 minutes of warm up and stretching, 40 minutes of pool exercises, and 5 to 10 minutes of exercises to cool down. Pool water was 33°C to 36°C (91.4°F–96.8°F). The pediatric aquatic therapy program was designed based on the Halliwick concept,²¹ which combines play, fun, self-help skills, and impairment-related goals. The Halliwick concept focuses on improving muscle strength, motor control in the trunk and extremities, circulation, breathing patterns, static and dynamic balance for gait patterns, and postural tone. Using this approach, program and individual functional goals were tailored to each participant's initial physical condition and activity level; otherwise, neurodevelopment concepts were integrated into the program according to the physical condition of each participant. Parents who participated in the aquatic exercise helped their child adapt to and function in the water environment. The intervention program comprised both aerobic and anaerobic training. For instance, for a 6-year-old boy who was diagnosed with spastic diplegia and who was Gross Motor Function Classification System level III, the therapist designed kicking activities with a kick board and water walking in shallow water as aerobic training; strength and resistance training as anaerobic training included toe raises and heel raises, balancing on one foot, squatting, jumping, and hopping. Exercise

intensity increased by repetition of each movement as the ability of the child improved. The goal was to improve gross motor ability in ambulation and participation safely while playing with peers.

Halliwick Concept

The Halliwick Concept was developed by James McMillan and has been applied to children with disabilities.^{5,21} For children with disabilities, hydrotherapy follows a 10-point program: mental adjustment; disengagement; transversal rotation control; sagittal rotation control; longitudinal rotation control; combined rotation control; up thrust; stillness balance; turbulent gliding, simple progression; and basic swimming movements.⁵

Demographic and clinical data

Baseline demographic data included age, gender, body height, and body weight (Table 1). Complications, goal achievement, and reasons and times of absence related to pediatric aquatic therapy were recorded. Clinical data were Gross Motor Function Classification System level, cerebral palsy subtype, and rehabilitation therapy applied. The Gross Motor Function Classification System level classifies the severity of motor disturbances and grade a child's self-initiated movements, emphasizing their functional abilities (ie, sitting, crawling, standing, and walking), and need for assistive devices (walkers, crutches, and canes) and wheeled mobility.¹⁶ The Gross Motor Function Classification System has a 5-point scale, ranging from level I for "independent" to level V for "dependent."¹⁶

Primary Outcome Measures

Primary outcome measures were Modified Ashworth Scale score,¹⁸ the 66-item Gross Motor Function Measure score, and Physical Activity Enjoyment Scale score.^{16,22} The Modified Ashworth Scale score was for the upper extremities (ie, elbow and wrist flexors) and lower extremities (ie, knee flexor and ankle plantar flexor) of the more-affected side (Table 2). Intraclass correlation coefficients of test-retest reliability and interrater reliability of the 66-item Gross Motor Function Measure are in the ranges 0.967 to 0.999 and 0.800 to

Table 1. Demographic and Clinical Data at Baseline of Pediatric Aquatic Therapy and Control Groups.^a

Data	PAT (n = 11)	Control (n = 13)	P
Baseline			
Demographic data			
Age (mo)	91.5 ± 36.5	80.5 ± 28.4	.582 ^b
Gender			
Male	4 (36.4)	9 (69.2)	.683 ^c
Female	7 (63.6)	4 (30.8)	
Body height (cm)	118.8 ± 17.8	114.6 ± 15.4	.794 ^b
Body weight (kg)	23.5 ± 10.5	19.6 ± 5.3	.561 ^b
Clinical data			
Rehabilitation			
PT (h/wk)	0.91 ± 0.54	1.15 ± 0.59	.253 ^b
OT (h/wk)	0.59 ± 0.49	1.23 ± 0.86	.107 ^b
CP subtypes			
Diplegia	3 (27.3)	6 (46.2)	.096 ^c
Quadriplegia	5 (45.5)	4 (30.8)	
Hemiplegia	3 (27.3)	3 (23.1)	
GMFCS level			
I	1 (9.1)	1 (7.7)	.149 ^d
II	4 (36.4)	6 (46.2)	
III	3 (27.3)	3 (23.1)	
IV	3 (27.3)	3 (23.1)	

Abbreviations: CP, cerebral palsy; GMFCS, Gross Motor Functional Classification System; OT, occupational therapy; PAT, pediatric aquatic therapy; PT, physical therapy.

^aValues are expressed as mean ± standard deviation or N (%)

^bIndependent 2-sample t-test.

^cFisher exact test.

^dMann-Whitney test.

*P < .05.

0.978, respectively.²³ The 66-item Gross Motor Function Measure score was derived by analysis of covariance of follow-up outcome values with correction for baseline differences (Table 2). Video recordings of 5 children with different Gross Motor Function Classification System levels were used to determine the interrater and intrarater reliabilities of the 66-item Gross Motor Function Measure before study start. The intraclass correlation coefficients for interrater and intrarater reliability of the 66-item Gross Motor Function Measure were 0.959 and 0.955, respectively.

Finally, the Physical Activity Enjoyment Scale, a well-defined tool with good validity and reliability,¹⁷ was applied to evaluate the physical activity enjoyment levels of each child after the intervention. For pediatric physical therapy, enjoyment or “feeling of fun” is important and affects participation of children with cerebral palsy; thus, this scale was appropriate.²

Secondary Outcome Measures

The secondary outcome measures were scores on the Vineland Adaptive Behavior Scale, Cerebral Palsy Quality-of-Life–parent proxy scale.^{24,25} The split-half and test-retest reliability coefficients for composite Vineland Adaptive Behavior Scale scores ranged from a median value of 0.83 for motor skills to a median value of 0.94 for the composite score.²⁴ Only the score on the activities of daily living domain of the Vineland Adaptive Behavior Scale was used as an outcome measure in this study. The Cerebral Palsy Quality-of-Life–parent proxy scale is a measure of health-related quality of life specific to children with

cerebral palsy.^{25,26} The Cerebral Palsy Quality-of-Life–parent proxy scale has 7 domains: social well-being and acceptance; participation and physical health; functioning; emotional well-being and self-esteem; pain and impact of disability; access to services; and family health. The algebraic mean of item values was calculated for each domain. As the mean increases, quality of life increases, except for the domain of pain and impact of disability. The parent-proxy of the Chinese Cerebral Palsy Quality-of-Life Questionnaire was used.²⁵ Internal consistency of this scale is 0.74 to 0.92 for primary caregivers. For primary caregivers, 2-week test-retest reliability is 0.76 to 0.89.²⁵

Data and Statistical Analyses

All of the posttreatment tests were performed within 1 week after the final intervention. Statistical analyses were conducted using the Statistical Package for the Social Sciences version 18.0. The independent 2-sample *t*-test was applied to continuous variables (ie, age, body height, body weight, treatment frequency, and Physical Activity Enjoyment Scale) and Fisher exact test was applied to categorical variables (ie, gender and cerebral palsy subtypes) to determine baseline differences between groups. The Mann-Whitney test was applied to analyze differences in ordinal data (Gross Motor Function Classification System level) between the 2 groups. To investigate whether the pediatric aquatic therapy group improved more than the control group at posttreatment, analysis of covariance was applied to each outcome variable (ie, Modified Ashworth Scale, 66-item Gross Motor Function Measure, Vineland Adaptive Behavior Scale, and Cerebral Palsy Quality-of-Life–parent proxy scale). Pretest performance was the covariate; group was the independent variable; and posttreatment performance scores were separate dependent variables. Effect size was calculated for each outcome variable to identify the magnitude of group differences. Large, moderate, and small effects were represented by an η^2 of ≥ 0.138 , 0.138 to 0.059, and 0.059 to 0.01, respectively. The Wilcoxon signed-rank test was applied to determine the 66-item Gross Motor Function Measure score change between the 2 groups by Gross Motor Function Classification System level (II-IV) and cerebral palsy subtypes. The participants with Gross Motor Function Classification System level I were not included in this analysis because their initial 66-item Gross Motor Function Measure score was 100 points. A *P*-value < .05 was considered statistically significant (1 tail).

Results

Baseline demographic data and clinical data, including treatment frequency for physical and occupational therapy, cerebral palsy subtypes, and Gross Motor Function Classification System levels, did not differ between the 2 groups (Table 1).

Mean attendance rate for the pediatric aquatic therapy group was 88.3%; the primary absence cause was upper respiratory tract infection. No pediatric aquatic therapy–related complications existed.

Descriptive Analysis

In terms of pediatric aquatic therapy goal achievement, 1 child achieved simple progression and 1 child needed turbulence guidance according the Halliwick 10-point program. Three children achieved independent balance in the water after 12

Table 2. Descriptive and Inferential Statistics for Analysis of Outcome Measures of Pediatric Aquatic Therapy and Control Groups.^a

Variables	Pretreatment		Posttreatment		ANCOVA		
	PAT (n = 11)	Control (n = 13)	PAT (n = 11)	Control (n = 13)	F _{1,17}	P value	Effect size η^2
MAS^b							
Ankle	2.1 ± 0.7	1.8 ± 0.6	2.1 ± 0.8	1.7 ± 0.8	0.263	.614	0.014
Knee	1.8 ± 0.8	1.3 ± 0.9	1.8 ± 0.8	1.3 ± 0.9	<0.001	1.000	0.904
Wrist	1.3 ± 0.8	1.3 ± 0.8	1.3 ± 0.8	0.9 ± 1	<0.001	1.000	<0.001
Elbow	1.3 ± 0.8	1.0 ± 1.1	1.3 ± 0.8	1.0 ± 1.1	<0.001	1.000	<0.001
GMFM-66	61.2 ± 18.7	64.6 ± 19.4	66.2 ± 18.2	65.3 ± 19.1	7.565	.007*	0.308
VABS							
Daily living	72.1 ± 48.5	93.7 ± 43.8	81.8 ± 48.9	92.1 ± 38.5	0.380	.393	0.023
CPQOL							
Social	64.5 ± 10.8	76.4 ± 8.9	76.5 ± 7.6	76.4 ± 10.8	0.187	.336	0.014
Functioning	64.8 ± 7.8	70.5 ± 16.2	68.6 ± 3.6	67.0 ± 14.3	0.060	.406	0.004
Participation	70.1 ± 8.6	70.5 ± 14.9	69.6 ± 8.3	68.5 ± 14.6	0.200	.332	0.018
Emotional	72.1 ± 7.1	63.5 ± 8.9	65.5 ± 9.0	62.3 ± 12.5	0.715	.201	0.046
Access	60.3 ± 16.5	64.4 ± 13.8	62.9 ± 10.6	63.5 ± 12.8	0.211	.327	0.017
Pain & Disability	41.1 ± 9.4	42.7 ± 14.8	37.1 ± 12.6	43.5 ± 16.3	0.493	.253	0.066
Family Health	68.0 ± 13.0	62.6 ± 11.7	63.1 ± 12.3	62.5 ± 17.8	1.405	.129	0.098

Abbreviations: ANCOVA, analysis of covariance; CPQOL, Cerebral Palsy Quality of Life Questionnaire; GMFM-66, Gross Motor Function Measure-66; MAS, modified Ashward score; PAT, pediatric aquatic therapy; SD, standard deviation; VABS, Vineland Adaptive Behavior Scale.

^aData were presented as the number or mean ± SD.

^bAnkle: the degree of spasticity of the ankle plantarflexor, more affected side; Knee: the degree of spasticity of the knee flexor, more affected side; Wrist: the degree of spasticity of the wrist flexor, more affected side; Elbow: the degree of spasticity of the elbow flexor, more affected side.

* $P < .05$.

weeks of intervention, 2 achieved combined rotation, 1 achieved longitudinal rotation, 2 achieved transverse rotation, and 1 achieve disengagement in the water. Participants at Gross Motor Function Classification System level II (60%) and with spastic diplegic cerebral palsy (75%) subtype made greater advances in goal achievement (more advance than balance in still water according to the Halliwick 10-point program) than those at other Gross Motor Function Classification System levels (33%) and with other cerebral palsy subtypes (29%).

Primary Outcome Measures

The analysis of covariance results demonstrate that pediatric aquatic therapy had a significant and large effect on 66-item Gross Motor Function Measure score (Table 2), with the pediatric aquatic therapy group experiencing a greater increase following intervention than the control group ($F_{1,17} = 7.565$, $\eta^2 = 0.308$, $P = .007$). Furthermore, the pediatric aquatic therapy improved average 66-item Gross Motor Function Measure score by 4.7 points. However, no posttreatment change existed for upper-limb and lower-limb Modified Ashworth Scale scores of both groups by analysis of covariance (Table 2). In light of physical activity enjoyment levels, the pediatric aquatic therapy group had significantly higher average postintervention Physical Activity Enjoyment Scale scores than the control group (pediatric aquatic therapy group, 98.9 ± 10.1 ; control group, 88.9 ± 16.9 ; $P = .015$).

The change in 66-item Gross Motor Function Measure score was associated with cerebral palsy subtypes and Gross Motor Function Classification System levels. The pediatric

aquatic therapy group improved more than the control group for children at Gross Motor Function Classification System level II ($P = .011$) and for children with the spastic diplegic subtype ($P = .032$), as determined by the Wilcoxon signed-rank test. Moreover, the change in 66-item Gross Motor Function Measure scores was greater in the pediatric aquatic therapy group than the control group, even for children with Gross Motor Function Classification System level IV (5.0 vs 1.3) (Figure 2).

Six children with Gross Motor Function Classification System level IV participated this study (Table 3): 3 in the pediatric aquatic therapy group and 3 in the control group. At posttreatment, children in the pediatric aquatic therapy group made greater gains in gross motor function and Physical Activity Enjoyment Scale scores than those in the control group (93-107 vs 62-79). For instance, case number 2 in the pediatric aquatic therapy group, an 8-year-old girl with quadriplegia, increased her Gross Motor Function Measure score by 10 points after 12 weeks of intervention. This child's Gross Motor Function Measure score change went from the 50-75th percentile to the >97th percentile based on the Reference Curve for Gross Motor Function Classification System level IV.²⁷ The other 2 children in the pediatric aquatic therapy group improved from the 25-50th percentile to the 50-75th percentile and from the 50-75th percentile to the 75-90th percentile, respectively (Table 3). However, Gross Motor Function Measure scores decreased (the same percentile at posttreatment based on the Reference Curve for Gross Motor Function Classification System level IV) for 2 of the 3 children in the control group at posttreatment.

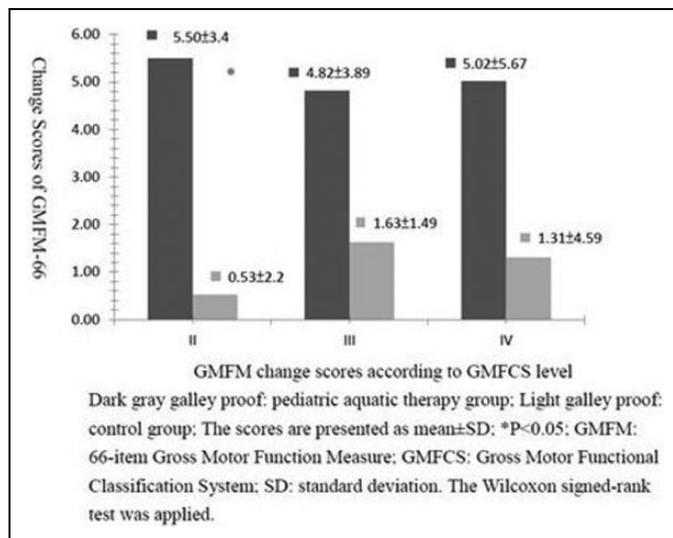


Figure 2. Sixty-six-item Gross Motor Function Measure (GMFM-66) change scores according to Gross Motor Function Classification System levels.

Secondary Outcome Measures

Descriptive statistics revealed that the activities of daily living domain of Vineland Adaptive Behavior Scale were comparable for both groups. However, analysis of covariance results show that no significant difference existed for the 2 groups in activities of daily living domain scores of Vineland Adaptive Behavior Scale following intervention (Table 2). For health-related quality of life, the Cerebral Palsy Quality-of-Life–parent proxy scale subscores or total scores did not differ between the 2 groups (Table 2).

Discussion

To our knowledge, this is the first study to investigate the effectiveness of pediatric aquatic therapy in improving motor function and enjoyment of therapy for children with spastic cerebral palsy of various motor severities. The pediatric aquatic therapy program improved gross motor function more (by 66-item Gross Motor Function Measure) and generated greater enjoyment than the conventional therapy (by Physical Activity Enjoyment Scale). However, the improvements in muscle tone, activities of daily living, and health-related quality of life were comparable for both groups. These findings suggest that pediatric aquatic therapy enhances motor function and enjoyment for children with spastic cerebral palsy, even for children with Gross Motor Function Classification System level IV who are very limited in their ability to perform land-based activities. However, the beneficial effects on pediatric aquatic therapy on motor function did not translate into improvements in activities of daily living and health-related quality of life.

Notably, pediatric aquatic therapy had beneficial effects on gross motor function as the average 66-item Gross Motor Function Measure score increased by 4.7 points. According to Wang and Yang,²⁸ 66-item Gross Motor Function Measure scores

≥ 3.7 indicate great improvement, scores of 1.6 to 3.6 indicate clinically meaningful improvement, and scores < 1.6 indicates no clinically meaningful improvement. An average improvement in 66-item Gross Motor Function Measure score of 3.2 points in 3.5 months following a land exercise was reported.²⁹ A possible explanation for the increase in the 66-item Gross Motor Function Measure score in the short period in this study may be that pediatric aquatic therapy exerts both thermal and mechanical effects. The thermal effects are beneficial for pain and spasticity reduction. The mechanical effects provide benefits by decreasing the influence of gravity and joint loading, and facilitating postural support and muscular strength.^{5,29} Another important explanation is that pediatric aquatic therapy promotes enjoyment, providing an opportunity to increase the motivation of both children and parents, facilitating motor performance improvement for children. This finding suggests that the pediatric aquatic therapy program in this study is an effective alternative to conventional therapy for children with spastic cerebral palsy.

Additionally, pediatric aquatic therapy is even beneficial for children with severe cerebral palsy. In this study, the improvement in 66-item Gross Motor Function Measure score was greater in the pediatric aquatic therapy group than the control group for children with Gross Motor Function Classification System level IV (5.0 vs 1.3). All children with Gross Motor Function Classification System level IV in the pediatric aquatic therapy group made greater gains in 66-item Gross Motor Function Measure score percentiles after intervention based on the reference curve for Gross Motor Function Classification System level IV. However, 2 children with Gross Motor Function Classification System level IV in the control group did not have changed 66-item Gross Motor Function Measure score percentiles.²⁷ Moreover, participants with Gross Motor Function Classification System levels IV in the pediatric aquatic therapy group had higher Physical Activity Enjoyment Scale scores than those in the control group. This analytical result is important for children with severe cerebral palsy because their ability to perform land-based physical activity is severely limited for children, and evidence is lacking that pediatric aquatic therapy positively affects children with Gross Motor Function Classification System level IV.^{3,4,31,32} Aquatic therapy reduces joint loading and engages children easily, assist therapists in strengthening, balance, and functional skills training, and reduces overuse syndrome.¹² Children with Gross Motor Function Classification System level IV increase their confidence and perform difficult tasks with little effort.³¹ Furthermore, aquatic therapy can be fun and enhance motivation.³ No side effect was reported during pediatric aquatic therapy in this study. These findings indicate that pediatric aquatic therapy is a safe and effective therapy for children with severe motor skill impairment.

The pediatric aquatic therapy participants with spastic diplegia and children with Gross Motor Function Classification System level II had greater improvement in their 66-item Gross Motor Function Measure scores than children with other Gross Motor Function Classification System levels and cerebral palsy

Table 3. Demographic and Clinical Data for Children Classified as Gross Motor Function Classification System Level IV.

Case number	Group	Age	Diagnosis	Gender	Initial GMFM score	Initial percentile	Final GMFM score	Final percentile	Change GMFM score	PACES score
2	PAT	8 y 6 mo	SQ	Female	45.91	50-75	57.33	>97	11.42	101
9	PAT	5 y 7 mo	SQ	Female	43.61	25-50	44.2	50-75	0.59	93
12	C	5 y 1 mo	SQ	Female	41.38	25-50	40.91	25-50	-0.47	62
14	C	5 y 5 mo	SQ	Male	42.2	25-50	48.73	75-90	6.53	77
19	PAT	11 y 11 mo	SQ	Male	42.85	50-75	45.91	75-90	3.06	107
28	C	9 y 8 mo	SQ	Female	40.2	25-50	38.08	25-50	-2.12	79

Abbreviations: C, control group; GMFM, 66-item Gross Motor Function Measure; PAT, pediatric aquatic therapy group; Percentile, percentile of GMFM-66 according to reference curve for gross motor function classification system level IV; PACES, Physical Activity Enjoyment Scale; SQ, spastic quadriplegia.

subtypes. The reason is likely that children with spastic diplegia or mild motor impairment had more opportunities to perform water exercises or activities than children with quadriplegia or more severe motor impairment. For instance, children with mild impairment, compared to children with marked impairment, performed more strengthening exercises, stretching exercises, and gross motor activities such as kicking and stroking.

Additionally, pediatric aquatic therapy induced more enjoyment than the control group. In this study, the pediatric aquatic therapy group had a better average mean Physical Activity Enjoyment Scale score than the control group. Children diagnosed with spastic cerebral palsy exhibit muscle weakness with spasticity, leading to poor joint alignment and contracture, causing pain and physical restrictions that compromise their health-related quality of life.⁹⁻¹¹ Pediatric aquatic therapy is characterized by more playful and non-weight-bearing exercises, requires less effort, and offers more pain-free activities, compared with conventional therapy.^{29,32} Repetitive strain injuries, such as tendinitis and muscular pain, are a typical problem of children with cerebral palsy. Additionally, their spastic-related energy expenditure and problems in transfer and locomotion generally reduce muscle endurance, muscle strength, balance, coordination, and motor skills. Low-impact aerobic exercise with resistive strength training and low risk of trauma or injury characterize pediatric aquatic therapy. These qualities enhance perceptions of pediatric aquatic therapy as more like play than exercise. Enjoyment is critical because it stimulates a child to participate in therapy, boosts his or her energy level, and motivates and stimulates the child to maintain a routine. These findings suggest the pediatric aquatic therapy is an effective alternative exercise for children with spastic cerebral palsy.

The beneficial effects on pediatric aquatic therapy, such as motor function improvements, did not translate into improvements in activities of daily living and health-related quality of life. One possibility is that the number of cases was too small and the intervention duration was too short (12 weeks) to observe the improvement in quality of life. The Vineland Adaptive Behavior Scale and Cerebral Palsy Quality of Life Questionnaire scale were completed by parents, and do not directly reflect the impressions of children. Additionally, posttest evaluation may have been too short to detect differences between the

2 groups. Further study with a larger sample size and longer follow-up is needed.

In this study, muscle tone did not differ between groups following the intervention. This finding is likely due to the small sample size and the fact that muscle tone was measured on a non-aquatic therapy day. Muscle tone typically decreases immediately after exercise, and then increases gradually hours later.^{33,34} Previous studies revealed that pediatric aquatic therapy can increase range of motion by increasing elasticity as a thermal effect.⁵ This study could not draw any conclusion for the effects of the pediatric aquatic therapy on spasticity management, such that further study is warranted.

The mean attendance rate of 88.3% for the pediatric aquatic therapy group was higher than that in previous studies.^{14,32,35} To increase attendance rates, future studies may conduct therapy at night or in the early evening and use community-based aquatic therapy.

Study Limitations

The findings are limited by the study design, including convenience sampling without randomization, a limited sample size, participant characteristics, and a short intervention period. Initially, the study design was a randomized controlled trial; however, most of the parents wanted to select their child's group based on personal preferences. In addition, in the conservative society of Taiwan, most parents of the participants would feel embarrassed to wear the swing suit in a public swimming pool to help their child adapt to and function in a water environment; some of the parents in this study requested to join the control group for this reason. Convenience sampling may cause selection bias. The 12-week intervention is too short to detect the health-related quality of life changes. An ethical issue exists when children with spastic cerebral palsy are assigned to the pediatric aquatic therapy group without conventional therapy; thus, comparing the effect of pediatric aquatic therapy alone with conventional therapy is difficult. The differences between groups in therapeutic dosage may have different effects. Pain intensity is not included as an outcome measure because this study includes preschool children. Bias and error are typical in visual pain scores, which are also subjective and lack reliability in children under the age of 6.³⁶ The Physical Activity Enjoyment Scale has not been validated for children with

cerebral palsy. Despite these limitations, positive effects of pediatric aquatic therapy on motor function and enjoyment were observed in children diagnosed with spastic cerebral palsy.

Conclusions

The pediatric aquatic therapy generated greater gains in gross motor function and physical activity enjoyment, especially for children with Gross Motor Function Classification System level II and the spastic diplegic subtype. Notably, pediatric aquatic therapy is a novel therapy for children with marked motor impairment because movement in land-based exercises is limited for this population. However, the beneficial effects on motor function did not translate into improvements in activities of daily living and health-related quality of life. This exploratory study confirms that pediatric aquatic therapy is a safe and effective alternative to land-based therapies, even for children with severe cerebral palsy. Future studies should include larger sample sizes, longer follow-up periods, different pediatric aquatic therapy protocols, such as community-based group therapy, and randomized controlled designs.

Acknowledgments

We are grateful for the participation of the children, their caregivers, and the Departments of Physical Medicine and Rehabilitation at Chang Gung Memorial Hospital and Taipei Veterans General Hospital. Ted Knoy is appreciated for his editorial assistance.

Author Contributions

C-JL, CLC, W-YL conceptualized the study and reviewed and interpreted the results and revised the manuscript at all stages. C-JL wrote the first manuscript. T-FY and C-YW organized and analyzed the data and revised the manuscript. R-CC approved the final manuscript. All authors contributed to the critique and review of the final draft of the article.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The authors would like to thank the National Science Council and Chang Gung Memorial Hospital, Taiwan, for financially/partially supporting this research under Contract No. NSC 101-2314-B-182-004-MY3 and No. CMRPG 3A0541, respectively.

Ethical Approval

This study was approved by the institutional review board of the Chang Gung Memorial Hospital. Participants and their parents or guardians provided informed consent. The clinical trial registration number of this study is as follows: 98-1947B; the Clinical Trial Protocol Registration System number is 01049581.

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