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Original Article

The effect of aquatic exercise on spasticity, quality of life, and motor function in cerebral palsy

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ABSTRACT

Objectives: The primary aim of this study was to compare the effects of aquatic exercises and land-based exercises on spasticity, quality of life, and motor function in children with cerebral palsy (CP). The secondary aim was to assess the morphology of spastic muscle using ultrasonography.

Patients and methods: Thirty-two children (17 boys, 15 girls; mean age 9.7±2.7 years; range 4 to 17 years) with CP were enrolled in this study. The patients were randomly assigned to two groups to receive 30 sessions of an aquatic or a land-based exercise program. The patients were assessed for the impairment level, functional measures, and quality of life before and after therapy. Ultrasonographic assessment of spastic gastrocnemius muscle was also performed.

Results: Both group showed significant improvements in most functional outcome measures. There were no significant differences in the percentage changes of the scores for functional outcome measures between the two groups. However, aquatic exercise produced a higher improvement in quality of life scores than the land-based exercises. Post-treatment ultrasonographic assessment of spastic gastrocnemius muscle showed a significant improvement in the compressibility ratio in the aquatic exercise group. The modified Ashworth Scale score of spastic gastrocnemius muscle in patients with CP showed a negative and weak-to-moderate correlation with the compressibility ratio based on the ultrasonographic evaluation.

Conclusion: Our study results suggest that the aquatic exercises are as effective as land-based exercises for spasticity management and motor function improvement in children with CP. Aquatic exercise can result in a higher level of improvement in quality of life scores than the land-based exercises. Ultrasonographic muscle compressibility ratio may be used to evaluate muscle elasticity in children with CP.

Keywords: Aquatic exercise; cerebral palsy; land-based exercise; spasticity; ultrasonography.

Cerebral palsy (CP) encompasses a heterogeneous group of early onset, non-progressive, neuromotor disorders which affect the developing fetal or infant brain.[1] The overall median prevalence estimate has been reported as 2.4 per 1,000 live births.[2] Children with CP have neurodevelopment disorders such as spasticity, contracture, reduced coordination, selective voluntary motor control, and muscle weakness.[3] Physical exercise can reduce many secondary conditions in patients with CP and can help improve posture, muscle tone, and balance.[4]

Land-based exercises including muscle-strengthening and stretching exercise programs increase the strength and improve gait performance, sit-to-stand capability, and functional performance in children with CP.[5,6] In a randomized controlled trial, a land-based exercise training program also improved the participation level and the quality of life in children with CP.[7]

Aquatic exercises are also beneficial in several musculoskeletal conditions and have become more popular in the recent years. It can be applied to children with CP to improve fitness and function, as the properties of water reduce excessive joint loading and enhance strengthening, providing assistance to children with decreased postural control and muscle

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weakness.[8] When the body is immersed in warm water (33 °C to 35 °C), the core temperature increases; thereby, leading to a reduction in gamma fiber activity which, in turn, reduces muscle spindle activity, facilitating muscle relaxation, and reducing spasticity. This results in an increased range of motion (ROM) in the joints and offers improved postural alignment.[8,9]

Aquatic therapy provides many advantages to experience, learn, and enjoy new movement skills, which leads to increased functional skills and mobility, and builds self-confidence. However, there are few studies investigating the effectiveness of aquatic exercise in children with CP. These studies have shown that aquatic exercise may be beneficial in children with CP to improve fitness and function. However, none of these studies used randomization, and/or used blinding, and/or included controls.[10-16]

Ultrasonography (USG) provides a safe, non-invasive, and relatively inexpensive method for the quantification of muscle architecture.[17] The measurement of muscle thickness with USG may provide an alternative method of the quantitative muscle evaluation.[18] Ultrasonography provides information about the muscle thickness, pennation angle, fiber length, and cross-sectional area; however, it is not useful for the assessment of the muscle stiffness, which is closely related to spasticity.[19] We, therefore, developed a new USG evaluation method for the assessment of the muscle stiffness, namely the "compressibility ratio" which was defined as the muscle thickness obtained with minimal consistent pressure of the probe divided by muscle thickness obtained with maximum consistent pressure of the probe. In a previous study, Tok et al.[20] reported that USG compressibility of spastic muscles may be used as an indicator of decreased muscle elasticity in chronic stroke survivors.

The primary aim of this study was to compare the effects of aquatic exercises and land-based exercises on spasticity, quality of life, and motor function in children with CP. The secondary aim was to clinically assess the morphology of spastic muscle and to evaluate the morphological changes during therapy using USG.

PATIENTS AND METHODS

A total of 32 patients (17 boys, 15 girls) with spastic type CP with a diagnosis of diplegia or hemiplegia from the outpatient physical medicine and rehabilitation clinic of our university hospital were enrolled in this prospective, comparative study between August 2012 and August 2013. Inclusion criteria for this study were as follows: a diagnosis of CP, age between 4 and 18 years, Grade ≥1 spasticity in the lower extremities according to the modified Ashworth Scale (MAS),[21] being able to respond to questions regarding their health status, being medically able to participate in an exercise program (no severe medical illness other than CP), being able to follow directions, and adherence to the exercise program. Children with open wounds, any known cardiovascular disease, recent (within the past 12 months) orthopedic surgical intervention, botulinum toxin A injection to lower extremities within the past six months, and fear of water were excluded from the study.

An informed consent was obtained from each participant and/or each parent before the examination. The study was approved by the local Ethics Committee of the university. The study was conducted in accordance with the principles of the Declaration of Helsinki.

The demographic and clinical features of the patients were noted. All patients were randomly assigned to two treatment groups including aquatic exercise group as the intervention group (Group 1; n=17) and land-based exercise group as the control group (Group 2; n=15). Randomization was allocated using numbered envelopes. Dosage of anti-spastic drugs, if used, was not changed during the study. In the aquatic exercise group, six children were classified as level I according to the Gross Motor Function Classification System (GMFCS).[22] There were six children with level II, three children with level III, and two children with level IV in the aquatic exercise group. In the land-based exercise group, there were six children with GMFCS level I, two children with level II, four children with level III, and three children with level IV.

One physical therapist (PT) experienced for aquatic therapy and two hydrotherapists who helped patients with aquatic exercise in the pool conducted aquatic exercise intervention sessions. Three other PTs conducted the land-based exercise sessions. All therapists including PTs and hydrotherapists had 2 to 10 years of experience in providing pediatric physical therapy intervention.

Aquatic exercise intervention

In Group 1, the patients performed the aquatic exercises under one-on-one supervision of a PT. The aquatic exercise program consisted of 30 sessions (five times per week for six weeks) in a swimming pool at 33 °C. Each session lasted 60 min. Each of 17 patients performed the same exercises; however, the exercises were individualized for each participant based on the number of repetitions and the intensity level which the patients were capable of. Progression was also scheduled on an individual basis. One or two hydrotherapists provided assistance to the PT during the aquatic exercise sessions according to each patient's needs. The program started with 10 min of poolside exercises including warming-up, active ROM exercises, and stretching, followed by 50 min of aquatic exercise in the pool. The pool session consisted of 25 min of aerobic exercise (such as walking forwards and backwards, swimming in the pool), 20 min of active ROM, stretching and strengthening exercises (strengthening of knee extensor, hip flexor, and ankle dorsiflexors) and 5 min of cool-down (such as slow walking and slow speed swimming). During muscular strengthening exercises for leg and trunk, aquatic noodles, leg weights, fins were used for 2 to 3 sets of 10 repetitions.

Land-based exercise intervention

In Group 2, the land-based exercise program consisted of 30 sessions (five times per week for six weeks). Each session lasted 60 min. The land-based exercise program started with 10 min of active ROM exercises and stretching exercises, followed by 30 min of aerobic exercise (cycle ergometer for lower limbs, etc.) and strengthening exercise (strengthening of knee extensor, hip flexor, or ankle dorsiflexor muscles). The exercise program continued with 20 min of sitting, standing, and gait training. Land-based exercises were given to each patient one-on-one by a PT.

Ultrasonographic evaluation

Ultrasonographic assessment of spastic gastrocnemius muscle was performed using a MyLab. 70 XVision Gold (Esaote Biomedica, Genoa, Italy) machine equipped with a multi-frequency linear array transducer (6-18 MHz) by a single physiatrist with a four year experience of musculoskeletal USG, who was blinded to both interventions. To assess the gastrocnemius medialis muscle thickness, participants were asked to lie prone on the bench with their feet hanging off the edge. The images of the spastic medial gastrocnemius muscle (for patients with spastic diplegia, the most spastic gastrocnemius was assessed) were obtained with the ankle joint in the neutral position. For standardization of the site of the measurements (muscle thickness, pennation angle, and fascicle length), the images were taken at proximal 30% of the tibial length as defined as the distance from the popliteal crease to the midpoint of the lateral malleolus. The probe was positioned perpendicular to the long axis of the leg, at the midpoint of the medial gastrocnemius muscle belly, half way between its medial and lateral borders. Minimal consistent pressure of the probe was maintained to avoid compression of the muscle fibers. The fascicle length was measured as the length of a fascicle between its insertions at the superficial and deep aponeurosis. The muscle thickness was defined as the perpendicular distance between the deep and superficial aponeurosis. The pennation angle was defined as the angle between the deep aponeurosis and the echoes of the interspaces between the fiber bundles.[23] For the measurement of compressibility ratio, the muscle thicknesses were measured during minimal and maximal consistent pressure of the probe which was tolerated by the patient. The compressibility ratio was calculated dividing muscle thickness during minimal probe pressure to the thickness measured during maximal probe pressure. Ultrasonographic assessment was performed before treatment (Week 0) and after treatment (Week 6).

Outcome measurements

Two physiatrists who were experienced in administering standardized tests to children with disabilities carried out the testing. Before the study, two physiatrists received training on the use of outcome measures. Before the treatment, one of the physiatrists evaluated the clinical assessment parameters. Post-treatment outcome measures were assessed by another physiatrist, all of whom were blinded to the interventions. Only a PT who did not carry out the measurements was unblended to the therapy. All patients were assessed for impairment level, functional measures, and quality of life. Evaluations were performed before treatment (Week 0) and after treatment (Week 6). All parents filled out the parent proxy-report, version of the Pediatric Quality of Life Inventory (PedsQL)-CP Module, to assess the quality of life in daily activities, school activities, movement and balance, pain and injury, fatigue, eating activities, and speech and communication.

The impairment level of the children with CP were assessed with GMFCS.[22] Spasticity was assessed using MAS.[21] Functional mobility was evaluated by the Timed Up and Go Test (TUG).[24,25] The Gross Motor Function Measure-88 (GMFM-88) was used to evaluate gross motor function in children with spastic CP.[26] The Wee Functional Independence

Measure (WeeFIM) was used to evaluate the severity of disability of children with CP.[27] The PedsQL-CP module was used to assess the quality of life in daily activities, school activities, movement and balance, pain and injury, fatigue, eating activities, and speech and communication. Both the child self-report version and the parent proxy-report version were used in this study.[28]

Statistical analysis

Statistical analysis was performed using the PASW for Windows version 18.0 software (SPSS Inc., Chicago, IL, USA). The distribution of data was evaluated using the Shapiro-Wilk test. All parametric (continuous variables with normal distribution) results were expressed in mean ± standard deviation for each group. Non-parametric variables were expressed in median and min-max values for each group. Numerical data with a normal distribution were analyzed with the independent sample t-test, while numerical data without a normal distribution and non-numerical data were analyzed with the Mann-Whitney U test. The paired t-test for numerical data with a normal distribution, and the Wilcoxon rank sum test for numerical data without a normal distribution and non-numerical data were used to compare pre- and post-treatment values within the groups. The chi-square test was used to compare categorical variables. The relationship between variables was assessed using the Spearman's correlation test. A two-tailed p value of <0.05 was considered statistically significant.

RESULTS

There were 17 children with CP (9 girls, 8 boys; 11 spastic diplegia, 6 hemiplegia) with a mean age of 10.1±2.4 years in the aquatic exercise group. There were 15 children with CP (6 girls, 9 boys; 10 spastic diplegia, 5 hemiplegia) with a mean age of 9.3±1.9 years in the land-based exercise group. There were no statistically significant differences in sex (p=0.502), age (p=0.627), and diplegia/hemiplegia ratio (p=0.907) between the groups. Baseline demographic characteristics of both groups are shown in Table 1. In addition, there were no statistically significant differences in the impairment level, functional measures, and PedsQL-CP module scores of the patients between the groups before the treatment (Table 2).

On the other hand, there were significant improvements in all post-treatment scores for lower extremity MAS, TUG, GMFM (in all dimensions and total score), total and motor WeeFIM, USG compressibility ratio of spastic gastrocnemius muscle, most subparts of child self-report-PedsQL (daily activities, school activities, movement and balance, pain and injury, eating activities subparts), and parent proxy-report-PedsQL (daily activities, movement and balance, school activities, pain and injury, fatigue subparts) in the aquatic exercise group

Table 1. Baseline values for impairment levels, functional measures, and ultrasonographic evaluation parameters of the groups

	Group 1 (n=17) Aquatic exercise group			Group 2 (n=15) Land based exercise group			
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p*
GMFCS		2	1-4		2	1-4	0.527
MAS RKF		0	0-2		1	0-3	0.239
MAS LKF		0	0-3		1	0-3	0.505
MAS RAF		2	1-3		3	0-4	0.280
MAS LAF		3	1-3		2	1-4	0.683
MAS RHA		1	0-1		1	0-3	0.430
MAS LHA		1	0-1		0	0-3	0.949
Timed Up and Go Test (sec)	13.9±5.6				14	9.4-40	0.799
GMFM		210	45-261		210	45-261	0.350
WeeFIM motor		82	27-91		78	15-90	0.411
WeeFIM cognitive		34	22-35		35	23-35	0.576
WeeFIM total		115	53-126		113	38-125	0.502
Gastrocnemius thickness (mm)	10.3±0.6			11.3±1.7			0.247
Fascicle length (mm)	30.4±8.4			31.8±9.7			0.672
Pennation angle (°)	20.5±4.1			22.2±7.7			0.431
Compressibility ratio		1.5	1.2-2.5		1.6	1.2-3.8	0.576

SD: Standard deviation; Min: Minimum; Max: Maximum; GMFCS: Gross Motor Function Classification System; MAS: Modified Ashworth scale; RKF: Right Knee Flexors; LKF: Left Knee Flexors; RAF: Right ankle plantar flexors; LAF: Left ankle plantar flexors; RHA: Right hip adductors; LHA: Left hip adductors; GMFM: The Gross Motor Function Measure-88; WeeFIM: Wee Functional Independence Measure.

Table 2. Comparison of the pre-treatment values for Pediatric Quality of Life Inventory of the groups

	Group 1 (n=17) Aquatic exercise group		Group 2 (n=15) Land based exercise group		
	Median	Min-Max	Median	Min-Max	*p*
Child Self Report-PedsQL					
Daily activities	73.6	5.5-100	65.3	0-100	0.595
School activities	87.5	37.5-100	87.5	18.8-100	0.781
Movement and balance	80.0	20-100	65.0	0-90	0.131
Pain and hurt	87.5	37.5-100	87.5	43-100	0.980
Fatigue	59.4	6.3-100	90.6	6.3-100	0.060
Eating activities	90.0	50-100	80.0	0-100	0.322
Speech and communication	87.5	37.5-100	100	37.5-100	0.347
Parent Report-PedsQL					
Daily activities	63.9	5.5-100	55.6	0-91.7	0.911
School activities	81.3	37.5-100	90.6	12.5-100	0.571
Movement and balance	62.5	15-100	60.0	15-75	0.628
Pain and hurt	78.0	50-94	75.0	62.5-87.5	0.433
Fatigue	56.3	0-100	71.9	37.5-100	0.201
Eating activities	77.5	50-100	80.0	0-100	0.970
Speech and communication	96.9	12.5-100	90.0	37.5-100	0.982

Min: Minimum; Max: Maximum; PedsQL: Pediatric Quality of Life Inventory.

(Tables 3 and 4). In the land-based exercise group, there were also significant improvements in all scores for lower extremity MAS (except left hip adductors), TUG, GMFM (in all dimensions and total score), total and motor WeeFIM, the movement and balance subpart of the child self-report-PedsQL, and some subparts of the parent proxy-report-PedsQL (movement and balance, pain and injury subparts) after treatment (Tables 5 and 6). (Data related to GMFM dimensions [A, B, C, D, E] not shown in Tables 3 and 5).

Since both groups showed a significant improvement in scores for MAS, TUG, GMFM (in all dimensions and total score), and total and motor WeeFIM at Week 6, we compared the percentage changes of continuous numerical data at Week 6 relative to pretreatment values. There were no significant differences in the percentage changes of the scores for TUG, GMFM (in all dimensions and total score), and total and motor WeeFIM between the two groups (Table 7). (Data related to the percentage

Table 3. The results and statistical comparisons of the baseline (Week 0), and post-treatment (Week 6) functional measures and ultrasonographic evaluation parameters in Group 1 (Aquatic exercise group) (n=17)

	Baseline (Week 0)			Post-treatment (Week 6)			
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p*
MAS RKF		0	0-2		0	0-1	0.039
MAS LKF		0	0-3		0	0-1	0.003
MAS RAF		2	1-3		1	0-3	0.005
MAS LAF		3	1-3		2	0-3	0.046
MAS RHA		1	0-1		0	0-1	0.025
MAS LHA		1	0-1		0	0-1	0.003
Timed Up and Go Test (sec)	13.9±5.6			12.2±5.8			<0.001
GMFM		210	45-261	202.1±63.3			<0.001
WeeFIM motor		82	27-91		85	59-91	0.010
WeeFIM cognitive		34	22-35		34	29-35	0.083
WeeFIM total		115	53-126		120	92-126	0.010
Gastrocnemius thickness (mm)	10.3±0.6			10.4±0.7		0.329	
Fascicle length (mm)	30.4±8.4			28.7±8.9		0.419	
Pennation angle (°)	20.5±4.1			19.8±6.1		0.019	
Compressibility ratio		1.5	1.2-2.5	1.8±0.3	1.8	1.2-2.4	0.041

SD: Standard deviation; Min: Minimum; Max: Maximum; MAS: Modified Ashworth scale; RKF: Right Knee Flexors; LKF: Left Knee Flexors; RAF: Right ankle plantar flexors; LAF: Left ankle plantar flexors; RHA: Right hip adductors; LHA: Left hip adductors; GMFM: The Gross Motor Function Measure-88; WeeFIM: Wee Functional Independence Measure.

Table 4. The results and statistical comparisons of the baseline (Week 0) and post-treatment (Week 6) Pediatric Quality of Life Inventory values in Group 1 (Aquatic exercise group)

	Baseline (Week 0)		Post-treatment (Week 6)		
	Median	Min-Max	Median	Min-Max	*p*
Child Self Report-PedsQL					
Daily activities	73.6	5.5-100	83.3	5.6-100	0.018
School activities	87.5	37.5-100	100	56.3-100	0.026
Movement and balance	80.0	20-100	86	30-100	0.007
Pain and hurt	87.5	37.5-100	100	50-100	0.014
Fatigue	59.4	6.3-100	75	6.3-100	0.104
Eating activities	90.0	50-100	95	60-100	0.031
Speech and communication	87.5	37.5-100	87.5	31.3-100	0.194
Parent Report-PedsQL					
Daily activities	63.9	5.5-100	73.6	11.1-100	0.017
School activities	81.3	37.5-100	97	37.5-100	0.017
Movement and balance	62.5	15-100	70	30-100	0.004
Pain and hurt	78.0	50-94	93.8	77-100	0.001
Fatigue	56.3	0-100	68.8	6.3-100	0.005
Eating activities	77.5	50-100	85	50-100	0.066
Speech and communication	96.9	12.5-100	100	12.5-100	0.397

Min: Minimum; Max: Maximum; PedsQL: Pediatric Quality of Life Inventory.

changes of GMFM dimensions [A, B, C, D, E] at Week 6 relative to pretreatment values not shown in Table 7). There was no significant difference in the post-treatment MAS scores (categorical data) between the two groups (Table 8).

Post-treatment USG assessment of spastic gastrocnemius muscle showed a significant improvement in the compressibility ratio in the aquatic exercise group (Table 3). The MAS score of spastic gastrocnemius muscle in patients with CP showed negative and weak-to-moderate correlation with the compressibility ratio obtained from USG evaluation (r=-0.276, p<0.001). There was no correlation of the muscle thickness, pennation angle, and fascicle length of spastic gastrocnemius muscle obtained from USG evaluation with the MAS score of spastic gastrocnemius muscle (data not shown).

DISCUSSION

The major findings of this study were as follows: *(i)* Both aquatic exercise and land-based exercise equally improved all scores for lower extremity MAS, TUG,

Table 5. The results and statistical comparisons of the baseline (Week 0), and post-treatment (Week 6) functional measures and ultrasonographic evaluation parameters in Group 2 (Land-based exercise group) (n=15)

	Baseline (Week 0)			Post-treatment (Week 6)			
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p*
MAS RKF		1	0-3		0	0-2	0.008
MAS LKF		1	0-3		0	0-2	0.003
MAS RAF		3	0-4		1	0-3	0.001
MAS LAF		2	1-4		1	1-3	0.046
MAS RHA		1	0-3		0	0-2	0.083
MAS LHA		0	0-3		0	0-2	0.013
Timed Up and Go Test (sec)		14	9.4-40		12	8.5-29	0.008
GMFM		210	45-261		208	93-248	<0.001
WeeFIM motor		78	15-90		85	59-90	0.001
WeeFIM cognitive		35	23-35		35	32-35	0.102
WeeFIM total		113	38-125		120	94-125	0.001
Gastrocnemius thickness (mm)	11.3±1.7			11.4±2.1			0.698
Fascicle length (mm)	31.8±9.7			31.0±10.1			0.516
Pennation angle (°)	22.2±7.7			23.6±6.1			0.246
Compressibility ratio		1.6	1.2-3.8		1.7	1.4-3	0.008

SD: Standard deviation; Min: Minimum; Max: Maximum; RKF: Right Knee Flexors; LKF: Left Knee Flexors; RAF: Right ankle plantar flexors; LAF: Left ankle plantar flexors; RHA: Right hip adductors; LHA: Left hip adductors; GMFM: The Gross Motor Function Measure-88; WeeFIM: Wee Functional Independence Measure.

Table 6. The results and statistical comparisons of the baseline (Week 0) and post-treatment (Week 6) pediatric Quality of Life Inventory values in Group 2 (Land-based exercise group)

	Baseline (Week 0)		Post-treatment (Week 6)		
	Median	Min-Max	Median	Min-Max	*p*
Child Self Report-PedsQL					
Daily activities	65.3	0-100	73.6	0-100	0.345
School activities	87.5	18.8-100	90.6	18.8-100	0.083
Movement and balance	65.0	0-90	72.5	0-100	0.016
Pain and hurt	87.5	43-100	3.4	56.3-100	0.054
Fatigue	90.6	6.3-100	90.6	25-100	0.088
Eating activities	80.0	0-100	80	0-100	0.564
Speech and communication	100	37.5-100	100	37.5-100	0.180
Parent Report-PedsQL					
Daily activities	55.6	0-91.7	63.9	0-89	0.305
School activities	90.6	12.5-100	84.4	12.5-100	1.0
Movement and balance	60.0	15-75	65	15-90	0.009
Pain and hurt	75.0	62.5-87.5	64.6	69-94	0.001
Fatigue	71.9	37.5-100	81.3	37.5-100	0.268
Eating activities	80.0	0-100	80	0-100	0.655
Speech and communication	90.0	37.5-100	93.8	37.5-100	1.0

Min: Minimum; Max: Maximum; PedsQL: Pediatric Quality of Life Inventory.

GMFM (in all dimensions and total score), and total and motor WeeFIM in the children with CP; *(ii)* post-treatment results showed a higher improvement in the USG compressibility ratio, most subparts of child self-report-PedsQL, and parent proxy-report-PedsQL in the aquatic exercise group, compared to the land-based exercise group; and *(iii)* the MAS scores of spastic gastrocnemius muscle of the patients with CP showed a negative and weak-to-moderate correlation with the compressibility ratio based on the USG findings.

Table 7. Comparison of the two groups on the basis of the post-treatment percentage changes and difference on the scores of Timed Up and Go Test, The Gross Motor Function Measure, and Wee Functional Independence Measures relative to baseline values

	Group 1 (n=17)	Group 2 (n=15)	
	Aquatic exercise group	Land based exercise group	
	Mean±SD	Mean±SD	*p*
Timed Up and Go Test (sec)	-0.13 ±0.14	-0.16 ±0.13	0.664
GMFM	0.05 ±0.05	0.05 ±0.03	0.451
WeeFIM motor	0.04 ±0.04	0.06 ±0.06	0.860
WeeFIM cognitive	0.02 ±0.02	0.04 ±0.04	0.967
WeeFIM total	-0.13 ±0.14	-0.16 ±0.13	0.287

SD: Standard deviation; GMFM: The Gross Motor Function Measure-88; WeeFIM: Wee Functional Independence.

Table 8. Comparison of the two Groups on the basis of the post-treatment Modified Ashworth Spasticity score values

	Group 1 (n=17)		Group 2 (n=15)		
	Median	Min-Max	Median	Min-Max	*p*
Modified Ashworth scale					
RKF	0	0-1	0	0-2	0.078
LKF	0	0-1	0	0-2	0.106
RAF	1	0-3	1	0-3	0.658
LAF	2	0-3	1	1-3	0.184
RHA	0	0-1	0	0-2	0.162
LHA	0	0-1	0	0-2	0.205

RKF: Right Knee Flexors; LKF: Left Knee Flexors; RAF: Right ankle plantar flexors; LAF: Left ankle plantar flexors; RHA: Right hip adductors; LHA: Left hip adductors.

There are a few studies investigating the effectiveness of aquatic exercise in children with CP in the literature. Fragala-Pinkham et al.[10] conducted a non-randomized and non-controlled study in 16 children with disabilities to evaluate the effectiveness and safety of a group aquatic aerobic exercise program on the muscle strength, motor skills, and cardiorespiratory endurance. The authors found that aquatic exercise might provide a safe and beneficial alternative low-impact exercise for children with disabilities. In another study, the effects of an aquatic resistive exercise program on ambulatory children with CP were studied. The authors assessed the outcome of a 10-week aquatic therapy program on the leg strength, gait velocity, functional mobility, and balance, and reported a statistically significant increase in the GMFM part E and TUG after 10 weeks of aquatic therapy in their non-randomized and non-controlled study.[11] In a case series, four patients with cerebral palsy and juvenile idiopathic arthritis participated in aquatic and land-based physical therapy intervention. Clinically significant improvements in the functional mobility, walking endurance, range of motion, muscle strength, and/or pain reduction were documented in all four patients.[12] Ballaz et al.[14] investigated the effect and feasibility of a 10-week group aquatic training program on gait efficiency in adolescents with CP. They reported that group aquatic training increased gait efficiency in adolescents with CP. Similarly, in two other case studies,[13,15] beneficial effects of aquatic exercise were shown in a child with CP (single-subject design). In a recent study, Fragala-Pinkham et al.[16] evaluated the effectiveness of a 14-week aquatic exercise program on gross motor function, functional strength, aerobic capacity, balance, and walking endurance in children with CP. The authors found a significant improvement in the gross motor function and walking endurance, and concluded that ambulatory children with CP might improve their gross motor skills and walking endurance after an aquatic exercise program held twice per week for 14 weeks, utilizing moderate-to-vigorous exercise intensity and consisting of functional activities. All of these studies[10-16] were non-controlled and the interventions typically lasted for 45 to 60 min and were run two to three times per week for 10 to 14 weeks. Different from previous studies, our study included a control group and compared the effectiveness of two interventions on randomly selected CP patient groups. In our study, children with CP had a more intensive program (five times per week) for six weeks. We compared the effectiveness of aquatic exercise interventions with land-based exercises in the treatment of CP. However, we did found no significant differences in the functional outcome measures between the groups. One of the explanations for this result may be the relatively short duration of aquatic exercise training (six weeks) in the study group. In the aforementioned studies,[10-16] aquatic exercise training typically lasted for more than 10 weeks and up to 14 weeks. Since the duration and intensity are also critical factors in motor learning during physical therapy for children with CP, a longer aquatic exercise program (10 to 14 weeks) may produce a significant difference in functional outcome measures compared to a land-based exercise program. In addition, our study groups mostly included children with low GMFCS scores. Aquatic physical activity may be significantly beneficial for those with high GMFCS scores, that is, those with a significant movement restriction for whom land-based physical activity may be difficult and limited.[29,30] If we had conducted this study in children with higher GMFCS scores, we may have found significant differences between the groups. Furthermore, we conducted a single-blind, prospective, randomized study to prevent any bias during interpretation of study outcomes. The pre- and post-intervention assessments were not conducted by a single physician, and this could have contributed to the non-significant differences between the findings between the groups. In addition, our study design might cause low inter-rater reliability in all our test measures. Although our two investigators received the same training for the assessment of the outcome measures before the study, we are unable to know whether the findings of both physicians were within acceptable reliability ranges.

There were greater improvements in the post-treatment results in scores for most subparts of child self-report-PedsQL and parent proxy report-PedsQL in the aquatic exercise group than the land-based exercise group. One of the reasons for the greater improvements in the quality of life scores of the children with CP in the aquatic exercise group may be that the water provided a desirable environment for children and adolescents with CP. Weight-bearing requirements, the amount of trunk control, joint load, and effects of gravity are reduced in water.[31] A study has reported that performing motor skills in water can increase confidence, thereby, leading to less resistance for difficult tasks, compared to land-based training.[12] In addition, activities in the water can be fun and more interesting for children, potentially enhancing motivation.[13] Aquatic exercise provides the optimal environment for patients to exercise aerobically, and at higher intensities than would be possible on land, owing to the reduction of joint loading.[32] All of these factors could lead to happier children and their parents in the aquatic exercise group. Eventually, this might cause a higher increase in the quality of life scores in children with CP and their parents in the aquatic exercise group.

In addition, The MAS scores of spastic gastrocnemius muscle in the patients with CP showed a negative and weak-to-moderate correlation with the compressibility ratio obtained from USG evaluation (r= -0.276, p<0.001). Post-treatment results also showed a significant increase in the compressibility ratio in the aquatic exercise group along with a decrease in the MAS scores of the spastic gastrocnemius muscle. However, comparison of post-treatment MAS scores did not indicate a significant difference between the groups. These findings may suggest that the USG compressibility ratio may be more sensitive for the identification of small improvements (aquatic exercise might cause a slightly higher improvement in spasticity, compared to land-based exercise) in the spasticity of spastic gastrocnemius muscle in the patients with CP, compared to the classic MAS evaluation of spastic gastrocnemius muscle. In a case study, Tok et al.[20] used a different compressibility ratio ([muscle thickness obtained with minimal consistent pressure of the probe-muscle thickness obtained with maximum consistent pressure of the probe]/muscle thickness obtained with minimal consistent pressure of the probe × 100) to evaluate the effects of botulinum toxin A on the muscle architecture of spastic gastrocnemius muscle by USG evaluation. The authors found that compressibility of the gastrocnemius muscle was significantly impaired before and after botulinum toxin A injection. Therefore, they concluded that compressibility had a negative correlation with time after stroke onset, indicating decreased muscle elasticity in chronic stroke survivors. Our results showed that muscle compressibility ratio as a new sonographic parameter may be used to evaluate muscle elasticity, which is negatively affected in spastic muscle, in children with CP.

Nonetheless, the main limitation of this study was its small sample size. Further, large-scale studies may confirm or disprove some of the trends seen in the statistics. Another limitation of this study is that the total length of therapy was six weeks. Therefore, we were unable to evaluate patients six months after therapy to examine whether the benefits sustained. Additionally, there was no control group in the present study; hence, we were unable to investigate the placebo effect.

In conclusion, our study results show that aquatic exercises for spasticity and motor function are as effective as land-based exercises in children with CP. Aquatic exercises produce a higher improvement in quality of life scores than land-based exercise. However, further, randomized-controlled trials are needed to delineate the effectiveness of aquatic therapy in treating children with CP. In addition, we suggest that USG is a cost-effective and simple method for the morphological evaluation of the spastic gastrocnemius muscle in children with CP. The muscle compressibility ratio as a new USG parameter can be, therefore, used to evaluate muscle elasticity in children with CP.

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