

EFFICACY OF AQUATIC THERAPY IN IMPROVING FUNCTIONAL OUTCOMES IN CHILDREN WITH CEREBRAL PALSY: A SYSTEMATIC REVIEW

AMY TREMBACK-BALL, PHD, PT*; CHRISTOPHER BROZENA, DPT*; LAUREN CLEMSON, DPT*; KATLYNN FICKINGER, DPT*; NICOLE NAJAKA, DPT*

* Misericordia University, Dallas, PA USA

ABSTRACT

Purpose: This systematic review was conducted in order to determine if aquatic therapy is an effective intervention to improve treatment outcomes in children with cerebral palsy. **Methods:** CINAHL, Academic Search Premier, and Medline were searched for published research reports on the topic. **Studies were included if they met the criteria of population (aged 0-21), diagnosis (any form of cerebral palsy), and intervention (aquatic therapy). Studies that met inclusion and exclusion criteria were analyzed using the PEDro scale and summarized in a matrix. Results:** Fourteen studies were included. **Data were reported for a variety of functional measures, strength, ROM, energy expenditure, vital capacity, spasticity, gait, balance, emotional health, behavior, quality of life, and swimming ability. Conclusion:** The available evidence in this systematic review suggests that aquatic therapy is an effective intervention when used in conjunction with traditional physical therapy.

KEYWORDS: physical therapy; pediatrics, exercise

INTRODUCTION

Cerebral palsy (CP) is the most common neuromuscular disorder in children¹. This neurologic condition is caused by a non-progressive lesion in the immature brain which results in permanent impairments in movement and postures^{1,2}. CP can lead to diminished quality of life by limiting participation in both activities of daily living as well as various leisure activities secondary to physical disability¹. The reported incidence of this neuromuscular disease ranges from 1.5 to more than 4 per 1,000 live births³. CP can manifest during gestation, at birth, or immediately after birth. An interruption of oxygen to the brain of the fetus or newborn results in impairments that may include abnormal muscle tone and contraction, bone abnormalities, abnormal joint motion, muscle weakness, deficits in balance, changes in spinal reflexes, and low cardiovascular endurance^{4,5}. These impairments often have an effect on the attainment of developmental milestones so one may also see developmental delay^{4,6}. Further, the symptoms of CP can lead not only to physical disability in children but may also impair a child's social and psychological development as well.

The various types of CP are classified based on movement differences and include spastic diplegia, hemiplegia, quadriplegia, dyskinetic, ataxic, and mixed types⁷⁻⁹. The most common type of cerebral palsy is spastic CP, which typically affects the lower extremities more so than the upper extremities¹⁰. Children

with CP are often categorized into levels of severity based on their functional abilities with tools such as the Gross Motor Function Classification System (GMFCS). It is a five-level, age categorized system that emphasizes a child's performance in sitting, walking, and wheelchair mobility¹¹. The Gross Motor Function Measure (GMFM) is a more in depth, standardized tool for evaluating motor function in children with CP¹². This tool, which examines 5 dimensions of motor function and development, is the gold standard for evaluating the functional status of these individuals. These dimensions are outlined in Table 1. The type of CP, the GMFCS level, and the GMFM score all provide insight on how the disorder may impact the child's functional abilities at home, in the community, and overall quality of life.

Table 1 Gross Motor Function Measure

GMFM Section	Example Tasks
Section A: Lying & Rolling	Gathering to midline, reaching across midline, lifting head when prone.
Section B: Sitting	Pull to sitting, remaining upright with static sitting, reaching from sitting.
Section C: Crawling & Kneeling	Weight bearing through 4 points, reciprocal crawling, high kneeling.
Section D: Standing	Pull to stand, single leg stance, pick up object off floor.
Section E: Walking, Running, & Jumping	Cruising, ball kicking, hopping, stair navigation.

Children with CP are also susceptible to many associated conditions such as general deconditioning, overuse syndromes, contractures, and generalized weakness^{4,5}. This can result in decrease activity tolerance, decreased gait efficiency, and decreased postural and core stability. Because of this, children with CP may be less likely to participate in physical activity

For Correspondence:
AMY TREMBACK-BALL
Email: atball@misericordia.edu

than children without CP. Early diagnosis and a heavy emphasis on physical activity programs is a crucial part of the rehabilitation process to preserve activity and functional capabilities in children with CP¹⁰. Physical therapy is an essential part of the specialized interdisciplinary services that help children with CP reach their full potential and limit the impact of secondary impairments⁴. Physical therapy is often focused on increasing range of motion, strengthening musculature, reducing the risk of further complications, and improving functional independence¹³.

There are many traditional therapeutic exercises appropriate for the treatment of CP including treadmill training, running, cycle ergometer, and other land based exercises. However these activities have not always been considered “fun” for a child. This can negatively impact participation in treatment. Due to the natural qualities of water, aquatic therapy is an option to allow full participation in physical exercise that is more purposeful and enjoyable. Further, water provides a therapeutic environment because of its natural properties including viscosity, buoyancy and hydrodynamics. Preliminary research suggests that aquatic therapy activities allow unrestrained movement and facilitation of muscles that normally have difficulty overcoming gravitational forces to become unloaded and work with more ease¹⁰. Aquatic therapy can decrease many negative forces faced on land, while also permitting a variety of strengthening and aerobic exercises with the resistant forces of buoyancy and viscous drag to challenge the cardiovascular and musculoskeletal systems¹⁴. An individual submerged up to his/her umbilicus effectively loses approximately 50% of their body weight¹⁵.

Hydrodynamic forces of water can be used to support an individual as well as uniquely challenge them. While standing static the force of the water helps facilitate balance and proper posture, however when moving, drag safely adds an extra degree of challenge¹⁵. These forces can increase the demand not only on skeletal musculature but on the cardiovascular system as well¹⁵. Aquatic therapy may help train and strengthen the weakened respiratory muscles of individuals with CP. At rest the total work of breathing for a tidal volume of 1 liter increases 60% when submerged up to the neck¹⁵. It has been hypothesized that this can help train and strengthen the weakened respiratory muscles of individuals with CP and help improve the efficiency of cardiovascular and musculoskeletal systems. Lastly, the thermal properties of water may assist with achieving a better workout with individuals with high muscle tone. Heat transfer

from warm water to spastic muscles has been found to decrease spasticity and involuntary movements¹⁶.

PURPOSE

The purpose of this systematic review is to evaluate the efficacy of aquatic therapy programs in obtaining significant functional improvements in children with CP. This review aims to provide insight on aquatic therapy that can be adapted and practiced by current and future rehabilitation clinicians, especially physical therapists. The underlying goal of this review is to provide the latest research on aquatic therapy to healthcare professionals so that they may be educated and able to provide children with CP the most effective and beneficial treatments. This in turn may help optimize the children’s functional abilities and improve their overall quality of life.

METHODOLOGY

A search of the electronic databases CINAHL, Academic Search Premier, and MEDLINE was conducted using the term “cerebral palsy” in combination with each of the following: “aquatic therapy,” “aquatic exercise,” “hydrotherapy,” “children,” and “swimming.” The search was limited to journal articles written in English, published within the last 20 years (1994-August 2014), and all systematic reviews and meta-analyses were excluded. Additional articles were reviewed if they were referenced by an included article and appeared to meet the inclusion criteria.

Titles and abstracts were reviewed and the articles were included if they met the criteria of population (aged 0-21), diagnosis (any form of CP), and intervention (aquatic therapy). Case studies that included children with CP as well as other conditions were included if at least one participant had cerebral palsy.

Studies that met all inclusion criteria were individually analyzed and summarized in a matrix (Table 2) incorporating article reference, study type, PEDro score, number of subjects and groups used, diagnosis and functional inclusion/exclusion criteria, intervention performed, assessment tools utilized, intervention outcomes, study limitations, conclusions drawn from the study. PEDro score was taken from their official database when available or was determined by researcher consensus using the published PEDro scale¹⁷.

Table 2

Citation	Study Type	Petro Score	Number of Subjects/Groups	Ages of	Diagnoses & Functional Inclusion Criteria	Intervention	Assessment Tools	Significant Outcomes	Limitations	Conclusion
Ballaz, 2011 ¹⁴	Single Group Pre-Post	4	N=10 One Group: Aquatic Therapy	13-21 years old	Spastic CP Independent walking with or without device for 5 min. Ability to follow simple verbal instructions	45 minutes, 2x/week, 10 weeks 10 min warm up (stretching, aerobic exercise) 15 min relay race 5 min floating/relaxation 15 min aquatic play (balloon pass, synchronized swim, balance on a board, volleyball)	Energy expenditure index Gait analysis Isometric quad & hamstring strength GMFM (Parts D & E)	Decreased energy expenditure No significant gait change No significant strength change Significant GMFM change in only one subgroup	Program was not gait-specific; difficulty recording HR in the water; no control; short training period; small sample size	Group training is possible Cardio improvement was made Motor improvement may require more specificity
Chrysagis, 2009 ¹²	RCT	6	N=12 Two Groups: Aquatic Therapy & Control	13-20 years old	Spastic CP Tetraplegia or Diplegia Ability to walk with or without aids Ability to follow simple commands	~55 minutes, 2x/week, 10 weeks 10 min warm up (static stretching, walking) 35 min training in backstroke and front crawl Cool down (free swimming, stretching)	GMFM (Parts D & E) Modified Ashworth Scale (hip adductors and knee flexors) ROM (shoulder, hip, and knee)	GMFM increase approached significance Decreased spasticity scores for both hip adductors and knee flexors PROM for hip abduction and knee extension improved AROM for shoulder flexion and abduction also improved	Small sample size; different categories of spastic tetraplegia; familiarization of examiner; day to day changes in spasticity	Aquatic training can improve gross motor function, ROM, and spasticity
Lai, 2014 ¹⁸	NRT	8	N=24 Two Groups: Aquatic Therapy & Control	4-12 years old	Spastic CP GMFCS I-IV Ability to follow instructions	60 min, 2x/week, 12 weeks 5-10 min warm up and stretch 40 min. pool exercises (per Halliwick) 5-10 min cool down	Modified Ashworth Scale (elbow flexors, wrist flexors, knee flexors, plantar flexors) GMFM-66 Physical Activity	No significant difference in spasticity scores GMFM scores improved Increased Physical Activity score	Small sample size; short duration; final tests performed on a non-therapy day; lack of randomization; lack of pain measurement	GMFM improved but did not translate to ADL's or Quality of Life Higher Physical Activity Enjoyment rating may indicate improved compliance

Dimitrijevic 2012 ¹¹	RCT	5	N=27 Two Groups: Aquatic Therapy & Control	5-14 years old	CP	Ability to understand instructions	55 min, 2x/week, 6 weeks 10 min warm-up (aerobic exercises) 40 min swimming techniques (blowing bubbles, floating, gliding, swimming) 5 min play (ball games, chasing games)	Enjoyment Scale Vineland Adaptive Behavior Scale Cerebral Palsy Quality-of-Life parent proxy scale GMFM-88	No significant difference between groups No significant difference between groups GMFM scores improved Improved water orientation scores	Short intervention time; use of individualized aquatic intervention; control group received no intervention	Aquatic therapy can improve gross motor function
Dorval, 1996 ²⁵	RCT	5	N=20 Two Groups: Conventional Aquatic Therapy & Experimental Aquatic Therapy	10-17 years old	CP	Capable of following simple verbal orders	55 min, 1x/week, 10 weeks Conventional: Warm up & Relaxation 15 min swimming skills and games Free Play Cool down & Relaxation Experimental: Preparation and entry Warm-up Individual exercises Group Activities Relaxation *This group also received additional self-esteem training	Rosenberg's Self-Esteem Scale Functional Independence Measure for children	Both groups saw a short-term increase, no difference between groups. Conventional group saw a short-term increase, experimental group scores were increased both short term and at follow-up.	Small sample size; very limited response rate at nine-month follow-up; unbalanced use of emotional support	Aquatic exercise with both high and low amounts of structure show potential in improving self-esteem and functional independence in those with CP
Fragala-Pinkham, 2009 ²⁶	Case Study	3	N=2 Combination of Aquatic & Land Based Therapy	Case 1: 7 year old Case 2: Land old	Case 1: Spastic diplegia GMFCS level I Case 2: CP, Right		Case 1 – 2x/wk, 6 wks for 60 min (8 pool sessions & 4 land) Case 2 – 2x/wk for 60	Case 1- COPM, GMFM, 3 min fast walk, standing functional reach, peak isometric strength, PROM	Case 1 – Significant improvements in gross motor function, balance, & LE ROM	Patients received both aquatic therapy & land based therapy interventions; case study design, no control	Aquatic & land PT allowed for improvements in impairment for both children, including ROM, strength, balance, & functional mobility

				Case 2: 10 year old	hemiplegia. GMFCS level I	min for 2.5 months, then 1x/wk for 60 min for 5.5 months (76% of sessions in pool)	Case 2- COPM, PEDL, floor to stand, 3 min fast walk, timed single leg stance, MMT	Case 2 – Improvements on PEDL, floor to stand, ankle PROM, & 3 min fast walk		
Hurtzler, 1998 ⁴⁶	RCT	4	N=46 Two Groups: Aquatic Therapy & Control	5-7 years old	CP	30 min, 3x/week, 6 months 2x/week: Individual aquatic exercise 30 min water orientation and swimming skills 1x/week: Group movement exercise 30 min land based locomotion and ball-handling skills	Vital capacity Water orientation checklist	Both groups saw an increase in vital capacity; aquatic group's improvement was significantly greater than control Water orientation scores improved	Small sample size; more overall treatment time for experimental group; only examined vital capacity and not other indications of motor function	Aquatic therapy can show greater improved vital capacity in those with CP than more traditional PT
Jorgic, 2012 ⁴⁷	NRT	4	N=7 One Group: Aquatic Therapy	7-11 years old	Spastic CP Walk with/without assistive device Follow simple verbal instructions Any level of swimming ability Written consent from parents or physician	45 min, 2x/week, 6 weeks Hallwick Method, swimming exercises for healthy population(s)	GMFEM-88 Water Orientation Test Alyn 2	Increases were present in both section E and total scores Improved water orientation scores	Small sample size	Aquatic swimming programs have positive effects on the GMFEM D & E dimensions and overall improvement The A, B, & C dimensions didn't score high because of high score at baseline. These results are in accordance with prior research studies.
Maniu, 2013 ⁴⁸	Single Group Pre-Post	4	N = 24 One Group: Combination of Aquatic & Land Therapy	8-16 years old	Spastic CP, paraparesis, tetraparesis, hemiparesis, dyskinetic CP & ataxic CP Ability to follow simple verbal instructions	6 months, 2 weekly sessions of 45 min aquatic therapy & 2 land PT sessions Program for teaching swimming to individuals with neuromuscular disorders	Physical Activity Index Spirometry KINDLR	Increase in activity scores Vital capacity increased Improved KINDLR scores	No control group; received aquatic & regular PT; specific therapy intervention not reported	The combination of aquatic & land based PT can improve respiratory function in children with CP

Retarekar, 2009 ²¹	Single Subject Design	2	N=1 One Aquatic Exercise	5 years old Group: Aerobic	Spastic diplegia Medical stability or clearance No history of orthopedic surgery or botulinum injections Not receiving intervention that included aerobic endurance	3x/week, 12 weeks 1 rest day in between exercise day when possible 5 min warm up 30-40 aquatic aerobic exercise including treadmill walking, shuttle running, jumping, deep water running, creeping, 5 min cool down	COPM GMFM 6 Minute Walk Test Modified Energy Expenditure Index	Participation component consistently above +2SD at week 4. Satisfaction component showed improvement. Increase in GMFM scores, maintained through follow-up Walking endurance increased during intervention phase, but returned to baseline during follow-up Decreased energy expenditure during intervention, returned to baseline during follow-up	Small sample size; limited data collection during intervention phase; GMFM repeated multiple times- could have introduced training effect; moderate interrater reliability; no control group	Based on GMFM reference curves (mean change 3.3 points for child of her GMFM level and age), subject increased 10 percentile points which exceeds the predicted for short time frame. MEEI decreased. Walking endurance increased. Parent reported significant increase in mobility in home and classroom.
Fragala-Pinkham, 2014 ²²	Time Series Group Design	5	N=8 One Group: Aquatic exercise	6-15 years old	CP (GMFCS Level I or III) Walk with/without assistive device 6-18 years old Medically able to participate in exercise program Can follow directions and adhere to program No anticipated changes in meds/rehab	2x/week for 14 weeks 60 minute individual pool session - 2 to 5 min warm-up - 40 to 45 min aerobic exercise (70-80% MHR) - 5 to 10 min strength training - 5 to 10 minute cool down and stretch Aerobics included: Deep water walking, pool treadmill walking, step climbing, jumping, hopping, basketball drills, treading water, swimming, prone kicking Strength included:	GMFM D & E combined 6 Minute Walk Test Brockport modified curl-up / isometric push-ups / Lateral step-ups / Shuttle run test / Pediatric Berg Balance Scale	GMFM score improved Ambulation endurance improved All trended towards improvement but were not statistically significant	Small sample size; no control group; possible ceiling effect (GMFCS Level I); floor effect on muscular strength outcomes (GMFCS Level III); HR monitor problems; length of testing sessions varied	A 14-week aquatic exercise program can improve the gross motor skills and walking endurance in children with Cerebral Palsy who have mild-to-moderate physical impairments

Mackinnon ^{1997²²}		2	N=1	8 year old	services during study Willingness to enter water	Leg, arm, and trunk movements with noodles, leg weights, fins, and water resistance	Swimming With Independent Measurement GMFM Video analysis	Improvements in vertical and horizontal balance; able to float on back w/o aid and swim a short distance GMFM scores improved Improvement noted in confidence, single leg stance, balance; predominantly flat-footed gait w/ narrower base of support	Small sample size; lack of enthusiasm; patient reluctant to carry out session with mother	Doing Halliwick swimming with children who have spastic diplegia CP can improve both swimming and physical skills
Ozer, 2007 ²	RCT	6	N=23 Two Groups: Aquatic Therapy & Control	5-10 years old	Both groups consisted of children with tetraplegia, diplegia, or triplegia Ambulatory	14 week, 30min sessions, 3x/week First two weeks attempted to acclimate children to the pool After 2 weeks "exercises and drills" in water were started Aquatic Sports Skills Program started in 4th week (training session gradually increased to 60 min)	Body Awareness Child Behavior Checklist, parent and teacher forms	Swimming group saw scores increase No significant effect on internal or external behavior problems	Small sample size; not known; some of children's behavioral issues were not at the clinical level; no follow up of CBCL; CBCL limitations in applicability (life activities of children w/ mod/severe mental disability)	Swimming training produced a significant improvement in body awareness in children with CP, while no effect was evident on competence and behavior problems on CBCL
Thorpe, 2005 ²³	Single Group Pre-Post	5	N=7 One Group: Aquatic Therapy	7-13 years old	CP Able to ambulate 100 ft with or without a device Able to follow	45 min, 3x/week, 10 weeks Stretching and Warm-up Strengthening (hip flexors, hip abductors, hip extensors, knee flexors and extensors, hip	Lower extremity strength (isometric hip, knee and ankle flexors and extensors) Gait Velocity	Trended toward improvement but did not reach significance Trended toward improvement but did	Small sample size; limit to investigator bias; ambulatory children	Aquatic therapy can result in significant improvement in GMFM and Timed Up & Go scores

RESULTS

The electronic search of databases and inclusion criteria resulted in a total of 112 articles that were found (Figure 1). Of these articles, 14 were acceptable to be included in this literature review on the efficacy of aquatic therapy on the functional outcomes of children with CP. PEDro scores ranged from 2 to 8 points. The mean PEDro score of the articles included is 4.5 points. The PEDro score for each article is included in Table 2.

In the articles reviewed, there were a total of 212 participants aged 4-21 years old with the diagnosis of CP. The most frequently studied population was spastic CP. Tetraplegia, diplegia, paraparesis, hemiparesis, dyskinetic, and ataxic CP were also included in the articles selected. The number of participants ranged in each study ranged from 1 to 45 subjects. The studies included participants with varying levels of functional ability classified in respect to GMFCS levels with the following distribution: GMFCS level I (n=25), level II (n=33), level III (n=32), level IV (n=11), and level V (n=9). There were also 5 studies that did not use the levels of the GMFCS (n=102).

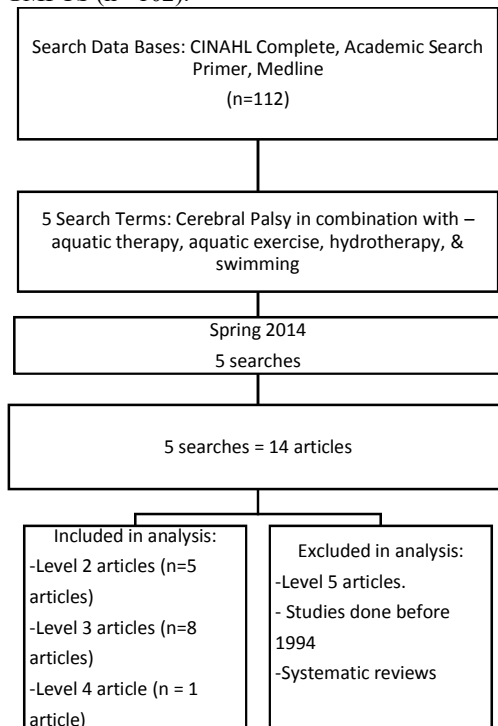


Figure 1:

Of the articles included in the review, 9 studies investigated aquatic therapy intervention alone. Of these 9 there were 2 articles that compared aquatic therapy to a control that

received conventional therapy, 1 study that compared an experimental aquatic therapy to a conventional aquatic control group and 1 study that compared their aquatic intervention to a no-intervention/control group. There were also 5 articles that participants received aquatic therapy along with conventional land based therapy. Eleven studies provided an aquatic intervention based on aerobic exercises that consisted of but is not limited to swimming skills, group activities, ball games, free play, individual aerobic exercise, strengthening exercises, and stretching. Two studies based their aquatic intervention on the Halliwick concept, which was developed by James McMillan and is often used for children with disabilities¹⁸. It follows a 10-point program addressing 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^{15,18}. Also, there was one study that focused their aquatic intervention on aquatic sports skills.

Functional gains were measured with a broad range of outcome measures. The researchers separated the different outcome measures into categories based on what each specifically measured. In total 29 different outcome measures were analyzed, ranging from simple strength measures to detailed standardized assessments. The findings of each study were organized based on the aspect of function examined: GMFM, other functional outcome measures, strength, range of motion, energy expenditure, respiratory capacity, spasticity, gait, balance, emotional health, behavior, quality of life, and swimming. These results are summarized in Table 3. Overall improvements were seen in 12 out of the 13 categories, with behavior being the lone exception.

Table 3:

Gross Motor Function Measure 10,13,14,18-24
8 out of 10 studies showed significant improvement in GMFM scores. Both 66 and 88 item versions of the GMFM were utilized. Section E typically saw the majority of the score improvement. Studies varied on which GMFCS levels saw significant score increases. Of the 3 studies that utilized a follow-up period >10 weeks, 2 indicated improvement was maintained.

Other Functional Outcome Measures ^{6,20,21,25,26}
Significant improvement in WeeFIM scores were found during intervention period.* Those with aquatic therapy and emotional support were able to maintain the WeeFIM improvements during follow-up. In a single-subject study improvements in PEDI scores were reported.* Increase in both activity participation and satisfaction observed using the COPM.
Strength ^{20,23}
Improvements on MMT measures. Increase in peak isometric strength of knee extensors, ankle DF, ankle PF >MDC. Increase in lower extremity strength. Increase in Knee flexor strength.*
ROM ^{10,20}
Changes in PROM/AROM of UE & LE.* Increase in PROM in ankle DF. Interaction effect for shoulder flexion, shoulder abduction, hip abduction, and knee extension.* Not a significant interaction effect of shoulder flexion and shoulder abduction. Decrease in popliteal angles, >MDC.
Energy Expenditure ^{14,23}
Decrease in energy expenditure during gait activities.* Decrease in walking HR.* GMFCS levels III-IV greater decreases in EEI vs GMFCS levels I-II. Increased gait efficiency during aquatic intervention phase.
Respiratory Volume ^{16,24,26}
Observable reduction in respiratory function of children with CP. Change in VC observed in treatment group. Increase in vital capacity*, increase of 56.7% compared to baseline. Aerobic capacity.*
Spasticity ¹⁹
Interaction found for spasticity of hip abduction and knee flexors.*
Gait ^{14,20,23,24}
Strong trend seen with increasing gait velocity with a mean overall increase in speed. Decrease in TUG scores. MDC in distance ambulated for 3 minute fast walk test. Improvements in walking endurance & >MDC walking speed. Increase in gait toe off variables.*
Balance ^{20,23}
Increase in trend of functional reach. Standing functional reach >MDC. Floor to stand transfer, MDC. Pediatric Berg Balance.*
Emotional Health ^{18,23,25}
Improvement in self-esteem. (significant pre-post intervention, but not pre-intervention to follow up) Greater enjoyment of intervention.
Behavior ^{6,18}
Comparable Vineland Adaptive Behavior Scale scores between aquatic and control groups. Aquatic therapy had no significant effect on internal or external behavior problems in the child behavior checklist.
Quality of Life ^{15,23,26}
More types of leisure activities. (Aquatic: 7, Conventional: 6) Health-related QOL comparable. Increase in KINDLR score (23.7%).* Significant increases were seen in KINDLR score for all GMFCS levels.*
Swimming ^{10,13,16,22}
WOTA2 increased in overall score, mental adaptation, and water movement/swimming pre to post intervention.* Maintained WOTA2 scores at follow-up. Improvement in water orientation.

DISCUSSION

While there is much research on the efficacy of traditional land based therapy on improving functional outcome measures in children with CP, research for the effectiveness of aquatic therapy is limited and in high demand. Despite increasing research into the benefits of aquatic therapy as a whole, only 14 articles were found examining its potential benefits in the treatment of children with cerebral palsy.

Of the ten included studies that looked at aquatic therapy's effects on GMFM score, eight saw significant improvement. Several of the studies looked specifically at improvements in section D (standing) and section E (walking, running, and jumping) of the GMFM. None of these studies saw a significant improvement in section D following aquatic treatment, and there were mixed results for improvement in section E. Part of this discrepancy may be the result of a ceiling effect. All participants needed to be able to ambulate for inclusion. Therefore, these individuals would presumably have a high starting section D score, and possibly a higher section E score. This potential ceiling effect is further supported by the fact that in these studies those individuals with GMFCS levels III-IV saw greater improvement than those in levels I-II. Significant functional improvements were also observed in the WeeFIM and PEDI, indicating that these improvements can be generalized beyond a single evaluation tool.

The results of this review suggest that these improvements in functional scores were the result of improvements in a variety of aspects of function. Improvements in strength, range of motion, and spasticity indicate that aquatic therapy can positively impact some of the primary musculoskeletal effects of cerebral palsy. These results demonstrate that water can be used to provide adequate resistance to result in strength increases in this population. Improvements in range of motion and spasticity indicate that aquatic therapy may also be effective in preventing contractures, and subsequent surgical releases, in this population. Further research in this area could be very valuable.

One of the most restrictive effects of CP is its impact on a child's ability to ambulate independently. In addition to score improvements in the GMFM's walking, running and jumping section, several other aspects of effective gait saw improvements. Patient balance improved following aquatic treatment, potentially decreasing risk for falls. In addition, improvements in vital capacity and energy expenditure index indicate that aquatic therapy may allow children to ambulate as well as

participate in other activities for longer periods of time without the threat of fatigue. Future research in this area could be used to determine if aquatic therapy can be utilized to decrease a child's reliance on assistive devices when ambulating. This could have significant implications for not only improvement in function but also improving limitation in participation and social restrictions associated with the use of assistive devices.

Along with gross motor improvements seen in the research, the participation component of programs is crucial for measuring their effectiveness on improved function. Participation measures such as the Canadian Occupational Performance Measure (COPM) are important for understanding the consistency and validity of results obtained throughout the program itself. Fragala-Pinkham et al²⁰ reported that the number of missed appointments was reduced when a child's PT program included aquatic intervention with an increase in motivation and decline in behavior-related obstacles.

Several of the studies reviewed suggest that the potential benefits of aquatic therapy extend beyond improvements in physical condition. These studies indicate that one's emotional health and quality of life may also benefit from these treatments. Aquatic therapy is an environment that encourages the formation of new friendships, not only with peers, but also with teachers and therapists that may be involved in treatment. These new interpersonal relationships help these children gain a sense of social satisfaction and self-esteem. This form of therapy also provides these children with new skills that allow them to be more active in their daily lives. In addition, these swimming skills provide them with the opportunity to participate in a leisure activity or sport for the rest of their lives.

When analyzing the research included in this review there were a number of limitations that were common among several of the articles. Many studies only included a small number of subjects. Other studies have noted that secondary to the diversity of characteristics in children with CP it is difficult to conduct large group randomized control trials²⁷. Due to the limited and lack of well-defined research, small group interventions and case studies were included due to their well-described intervention protocols. It was also notable that several of the studies did not include detailed information regarding the types of aquatic intervention performed. Since different types of interventions can lead to very different outcomes, detailed intervention information should be included in all future studies. In addition, several of the studies did not

include control groups, likely as a result of small sample sizes.

Currently, research into the efficacy of specific aquatic interventions is minimal. Almost all of the studies included analyzed the effectiveness of an aquatic intervention in relation to conventional treatments. As aquatic therapy broadly becomes better recognized as an effective way to help individuals with CP, more research will need to be done to identify which specific aquatic interventions are most effective for which symptoms. Furthermore, research needs to be conducted in order to determine how to get the best interaction between land-based and aquatic treatments. Additional research will also need to be completed to look at the relationship between program length and optimal changes in functional status. Future research studies and systematic reviews would need to be conducted to help establish a baseline or gold standard as far of what is the effective frequency and duration for an aquatic therapy program for improving overall function in children with CP.

CONCLUSION AND IMPLICATIONS FOR RESEARCH AND CLINICAL PRACTICE

Current research supports the benefits of land and aquatic therapy when used in conjunction with one another. However, research is limited when comparing one form of therapy to the other. It is with confidence that this systematic review presents the beneficial effects of aquatic therapy in conjunction with traditional therapy in improving functional outcome measures in children with CP. Improvements in functional outcome measures can be seen through positive changes including but not limited to ROM, strength, balance, spasticity, and mobility. While further research is needed to identify best practices for aquatic therapy, future clinicians should consider using therapy under aquatic conditions in addition to traditional therapy for children with CP. Traditional therapy should not be undervalued after this evaluation of research; however, it is with our hope that clinicians and therapists will consider adding therapy under aquatic conditions to their practice in order to help achieve functional gains for children with CP and allow for an improved quality of life.

REFERENCES

1. Rosenbaum P, Stewart D. The World Health Organization International Classification of Functioning, Disability and Health: a model to guide clinical thinking, practice and

- research in the field of cerebral palsy. *SeminPediatr Neurol.* 2004;11:5-10.
2. Auxter D, Pyfer J, Heuttig C. Principles and methods of adapted physical education and recreation. 10th ed. St. Louis, MO: McGraw-Hill; 2005.
3. Data and Statistics for Cerebral Palsy. Centers for Disease Control and Prevention Web site. <http://www.cdc.gov/NCBDDD/cp/data.html> Published December 27, 2013. Accessed January 20, 2015.
4. Beckung E, Hagberg G. Neuroimpairments, activity, limitations and participation restrictions in children with cerebral palsy. *Dev Med Child Neurol.* 2002;44:309-316.
5. Laskin JJ. Cerebral palsy. In ACSM's Exercise Management for Persons with Chronic Diseases and Disabilities. Champaign: Human Kinetics; 2003:288-294.
6. Ozer D, Nalbant S, Aktop A, Duman O, Keleş I, Toraman NF. Swimming training program for children with cerebral palsy: body perceptions, problem behaviour, and competence. *Percept Mot Skills.* 2007;105:777-87.
7. Cans, C. Surveillance of cerebral palsy in Europe: A collaboration of cerebral palsy surveys and registers. *Dev Med Child Neurol.* 2000;42:816-824.
8. Sanger TD, Delgado MR, Gaebler-Sira, et al. Taskforce on Childhood Motor Disorders. Definitions and classification of negative motor signs in childhood. *Pediatr.* 2006;118:2159-2167.
9. Sanger TD, Delgado MR, Gaebler-Spira, et al. Taskforce on Childhood Motor Disorders. Classifications and definition of disorders causing hypertonia in childhood. *Pediatr.* 2003; 111:e89-e97.
10. Jorgić B, Dimitrijević L, Aleksandrović M, Okicic T, Madic D, Radovanovic D. The swimming program effects on the gross motor function, mental adjustment to the aquatic environment, and swimming skills in children with cerebral palsy: A pilot study. *Serb J Sports Sci.* 2012;11:51-66.
11. Palisano RJ, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol.* 1997; 39: 214-223.
12. Russell D, Rosenbaum P, Cadman D, Gowland, C, Hardy S, Jarvis S. The gross motor function measure: a means to evaluate the effects of physical therapy. *Dev Med Child Neurol.* 1998;31:341-352.
13. Dimitrijević L, Aleksandrović M, Madić D, Okičić T, Radovanović D, Daly D. The effect of aquatic intervention on the gross motor function and aquatic skills in children with cerebral palsy. *JHumKinet.* 2012;32:167-74.
14. Ballaz L, Plamondon S, Lemay M. Group aquatic training improves gait efficiency in adolescents with cerebral palsy. *DisabilRehabil.* 2011;33:1616-24.
15. Becker B. Aquatic therapy: scientific foundations and clinical rehabilitation applications. *Am J Phys Med Rehabil.* 2009;1:859-872.
16. Hutzler Y, Chacham A, Bergman U. Effects of a movement and swimming program on vital capacity and water orientation skills of children with cerebral palsy. *Dev Med Child Neurol.* 1998;40:176–181.
17. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. *PhysTher.* 2003;83: 713-721.
18. Lai CJ, Liu WY, Yang TF, Chen CL, Wu CY, Chan RC. Pediatric aquatic therapy on motor function and enjoyment in children diagnosed with cerebral palsy of various motor severities. *J Child Neurol.* 2014;1-9. doi: 10.1177/0883073814535491.
19. Chrysagis DN, Douka A, Nikopoulos M, Apostolopoulou F, Koutsouki D. Effects of an aquatic program on gross motor function of children with spastic cerebral palsy. *BiolExerc.* 2009;5:13-25.
20. Fragala-Pinkham MA, Dumas HM, Barlow CA, Pasternak A. An aquatic physical therapy program at a pediatric rehabilitation hospital: a case series. *PediatrPhysTher.* 2009;21:68-78.
21. Retarekar R, Fragala-pinkham MA, Townsend EL. Effects of aquatic aerobic exercise for a child with cerebral palsy: single-subject design. *PediatrPhysTher.* 2009;21:336-44.
22. Mackinnon K. An evaluation of the benefits of halliwick swimming on a child with mild spastic diplegia. *APCP J.* 1997;30-39.
23. Thorpe DE, Reilly M, Case L. The effects of an aquatic resistive exercise program on ambulatory children with cerebral palsy. *J AquatPhysTher.* 2005;13:21-34.
24. Fragala-Pinkham MA, Smith HJ, Lombard KA, Barlow C, O'neil ME. Aquatic aerobic exercise for children with cerebral palsy: a pilot intervention study. *Physiother Theory Pract.* 2014;30:69-78.
25. Dorval G, Tetreault S, Caron C. Impact of aquatic programmes on adolescents with cerebral palsy. *OccupTher Int.* 1996;3:241-261.
26. Maniu DA, Maniu EA, Benga I. Effects of an aquatic therapy program on vital

- capacity, quality of life and physical activity index in children with cerebral palsy. HVM Bioflux2013;5:117-124.
27. Getz M, Hutzler Y, Vermeer A. Effects of aquatic interventions in children with neuromotor impairments: a systematic review of the literature. ClinRehabil. 2006;20:927-36.