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ORIGINAL PAPER

The Effectiveness of Aquatic Group Therapy for Improving Water Safety and Social Interactions in Children with Autism Spectrum Disorder: A Pilot Program

Michele L. Alaniz[1] · **Sheila S. Rosenberg**[1,2] · **Nicole R. Beard**[1,3,4] · **Emily R. Rosario**[1,2]

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Abstract Drowning is the number one cause of accidental death in children with Autism Spectrum Disorder (ASD). Few studies have examined the effectiveness of swim instruction for improving water safety skills in children with moderate to severe ASD. This study examines the feasibility and effectiveness of an aquatic therapy program on water safety and social skills in children with mild to severe ASD (n = 7). Water safety skills were evaluated using the Aquatics Skills Checklist and social skills were measured using the Social Skills Improvement Scale. We provide preliminary evidence that children with ASD can improve water safety skills (p = 0.0002), which are important for drowning prevention after only 8 h of intervention. However, social skills did not respond to intervention (p = 0.6409).

Keywords Aquatic therapy · Autism spectrum disorder · Social skills · Occupational therapy · Swimming · Drowning prevention

Introduction

Autism spectrum disorder (ASD) impacts one in 68 children (Christensen et al. 2016) and is characterized by difficulties in socialization and communication and restricted, stereotypical behaviors (APA 2013). Swimming and water play are becoming increasingly common activities for children with ASD (Little et al. 2014). In fact, families who have children with disabilities identify swimming as their most popular physical activity and overall favorite activity (Mactavish et al. 2000). Children find water play irresistible and the pull to explore the water is strong. Unfortunately, every day two children under the age of 14 die from accidental drowning (Gilchrist et al. 2014). Drowning is the second leading cause of unintentional injury deaths among United States (US) children between the ages of one and 15 (Dellinger and Gilchrist 2017). These findings indicate that water safety skills in children are of vital importance. Children with ASD are even more likely than their typically developing peers to be victims of accidental drowning (Shavelle et al. 2001). According to the National Autism Association, 91% of the total deaths in the US in children with ASD under the age of 14 were a result of accidental drowning after wandering/elopement (McIIwain and Fournier 2012), making it the number one cause of accidental death in children with ASD (Shavelle et al. 2001).

Participation in formal swim lessons has been associated with an 88% reduction in the risk of drowning in young children (Brenner et al. 2009). Researchers have found that 74% of drowning victims in the US did not know how to swim (Morrongiello et al. 2013). Although no significant statistical association has been established between swim lessons and drowning rates in older children, there is evidence to indicate that lessons may serve a protective function (Brenner et al. 2003; Weiss et al. 2010). In fact, the literature suggests that drowning prevention for school-aged children begins with swim lessons (Schnake et al. 2005). Swim lessons are a common part of childhood and are available through most city programs in the US each summer. However, children with

✉ Michele L. Alaniz
malaniz@casacolina.org

1 Children's Services Center, Casa Colina Hospital and Centers for Healthcare, 255 E. Bonita Ave., P.O. Box 6001, Pomona, CA 91769, USA

2 Casa Colina's Research Institute, Pomona, CA, USA

3 Curative New Berlin Therapies, New Berlin, WI, USA

4 Children's Services Center, University of Southern California, Los Angeles, CA, USA

ASD often exhibit unique motor learning challenges (Pan et al. 2009; Staples and Reid 2010), along with impaired communication and receptive language skills (Howlin et al. 2014), limiting their opportunities to participate in community based swim lessons. Therefore, parents often turn to the professionals who work with children with disabilities to help them learn to swim. A number of studies have demonstrated that intervention is effective for improving the swim skills of children with ASD (Chu and Pan 2012; Fragala-Pinkham et al. 2011; Pan 2010; Pan et al. 2011; Rogers et al. 2010; Yanardag et al. 2013; Yilmaz et al. 2005, 2010, 2004). However, the evidence base remains shallow due to limited sample sizes, criteria that exclude children with moderate to severe ASD, and exceptionally high treatment dosages.

Swim Skills in Children with Mild to Severe ASD

Children with ASD present with varying expressions of symptoms, ranging from mild to severe. The DSM-5 includes a severity rating scale to allow clinicians to indicate the extent of the symptoms that are present in children with ASD (Table 1). Severity levels range from "requiring support" (level one—mild ASD) to "requiring very substantial support" (level three—severe ASD). Symptoms are considered in relation to social communication impairments as well as restricted, repetitive behaviors. Children classified as level three or severe ASD demonstrate little to no verbal skills and very limited social interactions. In addition, these children display inflexible behavior that interferes markedly with function (APA 2013).

A systematic review published in 2015 indicated that in the past 10 years, 13 studies have evaluated the effects of aquatic activities on physical fitness and aquatic skills in children with ASD (Aleksandrovic et al. 2015). Eight of the studies reviewed did not provide enough information to determine the severity level of the participants and four of the studies included only high functioning children. Of the 13 studies, only one investigated the impact of aquatic based intervention on water skills in children with moderate to severe ASD. In addition, eight of the studies in the systematic review were single subject design, which limits the ability to generalize these findings.

Children with greater impairment require more support both socially and behaviorally in order to be successful with daily functioning (APA 2013). This makes them a vulnerable population because their impairments restrict their ability to access swim lessons that are provided by instructors who are untrained in working with the ASD population. Add to this the motor coordination delays commonly seen in children with ASD (Whyatt and Craig 2012), and it is becomes clear that teaching water safety swim skills to children with moderate to severe ASD presents a unique challenge. More research is needed to determine if skilled, therapeutic

Table 1 DSM V clinician-rated severity of autism spectrum and social communication disorders

Severity level	Social communication	Restricted, repetitive behaviors
Level 3 "Requiring very substantial support"	Severe deficits in verbal and nonverbal social communication skills cause severe impairments in functioning, very limited initiation of social interactions, and minimal response to social overtures from others. For example, a person with few words of intelligible speech who rarely initiates interaction and, when he or she does, makes unusual approaches to meet needs only and responds to only very direct social approaches	Inflexibility of behavior, extreme difficulty coping with change, or other restricted/repetitive behaviors markedly interfere with functioning in all spheres. Great distress/difficulty changing focus or action
Level 2 "Requiring substantial support"	Marked deficits in verbal and nonverbal social communication skills; social impairments apparent even with supports in place; limited initiation of social interactions; and reduced or abnormal responses to social overtures from others. For example, a person who speaks simple sentences, whose interaction is limited to narrow special interests, and how has markedly odd nonverbal communication	Inflexibility of behavior, difficulty coping with change, or other restricted/repetitive behaviors appear frequently enough to be obvious to the casual observer and interfere with functioning in a variety of contexts. Distress and/or difficulty changing focus or action
Level 1 "Requiring support"	Without supports in place, deficits in social communication cause noticeable impairments. Difficulty initiating social interactions, and clear examples of atypical or unsuccessful response to social overtures of others. May appear to have decreased interest in social interactions. For example, a person who is able to speak in full sentences and engages in communication but whose to- and-fro conversation with others fails, and whose attempts to make friends are odd and typically unsuccessful	Inflexibility of behavior causes significant interference with functioning in one or more contexts. Difficulty switching between activities. Problems of organization and planning hamper independence

aquatic intervention is effective for improving water safety skills in the broader ASD population.

Dosage Requirements

Research has begun to establish the intensity of intervention required to demonstrate improvement in swim skills for children with ASD. Most studies have implemented a high frequency of weekly sessions (two to three times per week) as well as a one to one format. The literature indicates that children with high functioning ASD are able to improve swim skills after 18–36 h of intervention (Fragala-Pinkham et al. 2011; Pan et al. 2011; Yanardag et al. 2013). Two studies have considered the minimal dosing requirements for achieving swim skills in children with ASD. Pan and colleagues measured progress of 15 high functioning children with ASD after 14 h of intervention and again after 28 h of intervention. They found the greatest gains after 28 h of intervention (Pan et al. 2011). In contrast, Ennis evaluated the effectiveness of once a week physical therapy program for six children with mixed diagnoses (ASD, spina bifida, PDD-NOS, and ataxia) in the aquatic environment (Ennis 2011). Swim skills improved after 10 h of intervention. Continued gains in swim skills were seen after 20 h of intervention but to a lesser degree. Ennis recommended a dosage of 10 h of physical therapy and then continued practice facilitated by families outside of the therapeutic venue. More evidence is needed to determine the appropriate dosage and effectiveness of aquatic based therapy on improving swim skills in children with ASD of varying functional levels.

Social Skills in Aquatics

Impairment in social skills is a core feature of ASD (APA 2013). There is debate in the literature about the most effective way to improve this deficit. Interventions targeting social skill development either focus on developing pro-social behaviors or mitigating negative behaviors. Social skills training activities that occur in the child's natural environment appear to be more effective than "pull out" services (Bellini and Peters 2008). Researchers have put this theory to the test in the aquatic environment by embedding social skills instruction into water-based intervention. Chu utilized siblings and peers to facilitate swim and social skills during group swim classes. Utilizing video review, they evaluated social skills by measuring verbal and non-verbal communication with peers and adults during swim lessons. They found that spontaneous social interactions increased as a result of intervention (Chu and Pan 2012). Pan implemented a group aquatic intervention program that focused on aquatic skills without directly targeting social skills. Despite no direct social skills training, results revealed a reduction of anti-social behaviors after aquatic intervention. However, they did not observe improvements in pro-social behaviors (Pan 2010). Although promising, both of these studies excluded children with moderate to severe ASD and instead focused on high functioning children. There is a paucity of research evaluating the impact of aquatic based intervention on social skills in children with mild to severe ASD.

The purpose of the current study is to investigate the feasibility and impact of aquatic based occupational therapy provided in a small group setting on swim skills and social skills in children with mild to severe ASD. The research questions asked were as follows:

1. Do swim skills improve in children with mild to severe ASD after aquatic based occupational therapy intervention?
2. What is the minimum dosing required to achieve water safety skills in children with mild to severe ASD?
3. Do social skills in children with mild to severe ASD improve after aquatic based occupational therapy intervention?

We hypothesized that children with mild to severe ASD would improve in water skills and social skills after participating in 24 h of aquatic based occupational therapy.

Methods

Participants

Participants (n = 7) aged 3–7 years old (M = 6.095; SD = 0.236) with ASD were recruited from among the clients currently receiving therapy services at an outpatient pediatric clinic in Southern California. Flyers were posted at the clinic and given to parents of current clients. In addition, clinicians recommended participation in the study when they felt it was appropriate for their client. Participants continued their typical course of care, including therapy regimes, school programs and any other support service they were receiving, throughout their involvement in the study. Socioeconomic and race/ethnicity information was not obtained. A swim lesson history was gathered and five of the participants had no prior swim lesson experience due to their inability to access their community-based programs as a result of their disabilities. One participant had engaged in community based swim lessons prior to participating in the study but had failed to acquire swim safety skills due to his motor coordination and behavior impairments. An additional participant engaged in formal swim lessons provided by an occupational therapist prior to beginning the study. Inclusion criteria were: (1) a diagnosis of ASD as indicated by doctor prescription or a score of above average on the Autism Behavior

Rating subscale of the Social Skills Improvement System (SSIS) (Gresham and Elliott 2008) and (2) age 3–7 years old (Table 2). Subjects were rated for severity of ASD using the Clinician-Rated Severity of Autism Spectrum and Social Communication Disorders, a tool designed for research by the American Psychiatric Association (APA 2013). Ratings were assigned in collaboration between the primary investigator who was familiar with the subjects and had 13 years of experience working with children with autism and a licensed marriage family therapist qualified to provide psychiatric diagnosis. Video review, SSIS review and parent report were considered when rating ASD severity. Inclusion criteria were crafted to ensure that children of all functioning levels could participate in the study. Exclusion criteria were (1) open wounds, (2) an unpredictable bowel movement schedule, (3) infectious skin disease, acute respiratory infections or tracheotomy, (4) allergy to chlorine, and/or (5) serious motor/neurological problems. Four subjects were excluded from the study due to a failure to meet qualifications for an ASD diagnosis or failure to complete at least 8 h of treatment.

Instrumentation

Children who were eligible for the study engaged in a 1 h, individual testing session with an occupational therapist prior to beginning session one and again after session eight, session 16 and session 24. Swim skills were assessed using the Aquatic Skills Checklist (ASC), a tool developed by the researchers (Table 3) and based on the American Red Cross Water Safety Instructor Manual (2009). Testing was videotaped and the ASC was completed by video review. Video review was completed by an occupational therapist and a research assistant, independent of one another. Inter-rater agreement was 90%. Discrepancies were corrected by joint video review. 13 swim skills were measured by the ASC, these fell into six broader categories including pool navigation (moving along the wall when in the pool), breath control (blowing bubbles from mouth and nose and submerging face without water intake), propulsion (swimming five feet independently), exiting the water (pulling self out of the water using the wall, exiting at a ladder and exiting at stairs), back float, and changing positions when swimming (rotating on the body's axis to move from prone <-> supine). These

Table 2 Demographics of participants

	Sex	Age	Swim history	Autism severity level
Subject 1	Male	7.42 years	No history of swim lessons or aquatic therapy	Level 1—mild requiring support Spoke in complete sentences but demonstrated atypical social communication Required prompting to attend to the social overtures of others Demonstrated fixated interest
Subject 2	Male	7.42 years	No history of swim lessons or aquatic therapy	Level 3—severe requiring substantial support Intelligible words but rarely initiated communication Limited social interest Protested frequently and demonstrated inflexible behavior
Subject 3	Male	3.92 years	No history of swim lessons or aquatic therapy	Level 3—severe requiring substantial support Few intelligible words and often echolalic Limited social interest Cried frequently and demonstrated inflexible behavior
Subject 4	Male	5.42 years	No history of swim lessons or aquatic therapy	Level 3—severe requiring very substantial support Vocalized a few spontaneous words but primarily echolalic Very limited social interest Became distressed frequently
Subject 5	Male	6.08 years	Some private swim lessons prior to the study but did not acquire water safety	Level 1—mild requiring support Spoke in complete sentences but demonstrated atypical social communication Required prompting to attend to the social overtures of others Demonstrated inflexible and disorganized behavior
Subject 6	Male	6.33 years	Attended group swim lessons with an occupational therapist prior to the study	Level 2—moderate requiring substantial support Able to speak simple sentences but language impaired for age Required prompting to attend to the social overtures of others Demonstrated inflexible behavior and had difficulty waiting his turn
Subject 7	Female	4.50 years	No history of swim lessons or aquatic therapy	Level 3—severe requiring very substantial support Unable to speak and had no intelligible words Did not demonstrate social interest towards her peers Became distressed frequently and the antecedent was unclear

Table 3 Aquatic skills checklist (ASC)

1. Navigates pool by holding the pool wall and moving from one end to the other	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
2. Blows bubbles on the surface	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
3. Blows bubbles momentarily with mouth and nose submerged- independent if follows adult's modeling (if holding nose score as unable)	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
4. Submerges mouth, nose and eyes momentarily (if does with water intake score as unable; if holding nose, score as unable)	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
5. Propels self (using any position other than back swim) 5 consecutive feet (if unable, score #26 as unable)	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
6. Exits water at the side of the pool (not touching the pool floor)	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
7. Back floats momentarily *without physical support*- Back float is when the nipple line of the chest is above water, head is back, and arms and legs are not moving the majority of the time. If either of these criteria are not met, it is not a back float.	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
8. Assumes back float (tolerates moving into back float position momentarily)	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
9. Propels self on back 5 consecutive feet (on back or supine is when the nipple line is above the water)	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
10. Rolls from front to back	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
11. Rolls from back to front	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
12. Exits water safely at stairs	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)
13. Exits water using the ladder	☐ I (3)	☐ F (2)	☐ A (1)	☐ U/A (0)

skills were identified as being particularly important for water safety and drowning prevention. Each skill was rated on a scale of zero to three (0—unable to complete skill; 1—completed skill with physical assistance from therapist; 2—completed skill with a flotation device; 3—completed skill independently). Participants could acquire a maximum score of 39 points for the total ASC score.

Goals were structured using goal attainment scaling. Goal attainment scaling (GAS) is a criterion-referenced method of measuring change that involves collaboration between the therapist and client to create goals that are meaningful to the client (McDougall and Wright 2009; Miller et al. 2007). Possible performance outcomes are scored in five equal increments of change from −2 to +2, with the client's baseline level of performance at −1 (Miller et al. 2007). Following intervention, 0 is the expected level of outcome (McDougall and Wright 2009; Trombly et al. 2002). The GAS is more sensitive than other standardized outcome measures because it allows for five possible outcomes in terms of performance (Steenbeek et al. 2007). Although GAS is not standardized, researchers use it as a measurement of functional, meaningful, and individualized goals that are challenging to measure using standardized tests (Doig et al. 2010; Mailloux et al. 2007). For this study, a GAS manual was devised by the primary investigator to instruct the therapist assigning GAS goals in how to formulate goals that were clear, measurable and contained equidistant intervals. Families were interviewed using a written questionnaire to elicit their priorities for intervention. The primary occupational therapist assigned each participant three swim goals that were individualized to the participant and particularly relevant to the participant's family (Table 4). Because family priorities varied from one participant to another, GAS goals covered a broad spectrum of swim skills. However, the majority of GAS goals fell into three categories: breath control, propulsion and back float. These swim skill categories are particularly salient for drowning prevention. GAS goals were assigned at the beginning of each 8-week phase of intervention. GAS scores were obtained by video review of post testing completed by a research intern who was not involved in the intervention. GAS scores can be

Table 4 Goal attainment scaling example

Swim skills—propulsion	
−2	Subjects propels self for a distance of 2 feet independently
−1	BASELINE: Subject propels self for a distance of 6 feet independently
0	EXPECTED LEVEL OF PERFORMANCE: Subject propels self for a distance of 10 feet independently
+1	Subject propels self for a distance of 14 feet independently
+2	Subject propels self for a distance of 18 feet independently

converted to T scores using the formula described by (Ottenbacher and Cusick 1993):

$$T = 50 + \frac{\left(10 \sum W_i X_i\right)}{\sqrt{(1 - r) \sum W_i^2 + \left(\sum W_i\right)^2}}$$

Social skills were calculated using the Social Skills Improvement System (SSIS), a 79 item standardized questionnaire completed by the caregiver before session one and again after session eight, session 16 and session 24. The SSIS assesses social skills (communication, cooperation, assertion, responsibility, empathy, engagement, and self-control) and problem behaviors (externalizing, bullying, hyperactivity/ inattention, internalizing, and autism spectrum symptoms). It has demonstrated good test–retest reliability (r = 0.87) (Gresham and Elliott 2008).

Procedure

We used a single group pre-test post-test design. Intervention was implemented over three phases with eight 1-h sessions in each phase. Participants attended 8, 16, or 24 h of group intervention provided in 1-h increments, once a week. Intervention was led by a licensed and registered occupational therapist with 13 years of experience working with children with ASD, 11 years of experience teaching swim skills to children with autism, as well as specialized training in sensory integration intervention. Intervention was also implemented by a licensed speech and language pathologist with 4 years of experience working with children with ASD and 7 years of experience teaching swim lessons to neurotypical children. Sessions were implemented with a ratio of two participants for every one therapist, with no more than four participants in a group. Volunteer interns were also utilized to increase the adult to child ratio and to help ensure participant safety while in the pool. The primary volunteer had experience with teaching swim lessons to typical children, American Red Cross Aquatic Instructor Training and Lifeguard Certification. Despite this training, volunteers required extensive instruction from the occupational therapist to facilitate swim skills with the participants due to the challenge of working with this population. Participants presented with a variety of delays including sensory processing differences, poor motor planning, poor bilateral coordination, low muscle tone, weak musculature, impaired social referencing and imitation skills, expressive and receptive language delays, poor on task behavior, and poor impulse control. Intervention primarily leaned on the motor skill acquisition frame of reference, although components of the sensory integration frame of reference were also utilized. The intervention occurred in an indoor, heated, therapy pool, which was 20 feet wide and 30 feet long. Sessions followed a predictable pattern in which group activities were introduced and then graded to each individual's ability level (Table 5). Each participant engaged in tasks that targeted their underlying deficits while also providing contextual practice with augmented feedback. Modeling and physical guidance was also utilized to facilitate swim skills. Activity analysis was utilized to identify what therapeutic techniques would be most effective for each participant. A total of seven children participated in this study. Participants that completed one phase (n = 7) received 8 h of intervention. Of those, one met all therapeutic goals and discontinued intervention (subject five) and six participants completed two phases and received 16 h of intervention; of those, one met all therapeutic goals (subject three) and five participants completed three phases and received 24 h of intervention. After approval from the institutional review board, full consent and assent were obtained by legal surrogate for all children participating in the study.

Data Analysis

After confirmation that all assumptions were met (i.e., normality and sphericity), the aquatic skills data was analyzed using a repeated measure ANOVA and Wilcoxon signed rank to compare differences between pre and post intervention variables. The GAS data was assessed using the Wilcoxon signed rank for the difference pre and post the intervention. JMP was used for all data analysis (JMP Statistical Discovery from SAS, Cary, NC).

Results

Swim Skills and Dosing

Significant improvement in the overall swim skills score was observed over time (RM ANOVA: $F_{1,4} = 14.8$, $p = 0.0002$, Table 6; Fig. 1). This improvement in the overall swim skills score was noted after the initial 8 h of intervention (Wilcoxon: $S = 7.5$, $p = 0.03$) and again at 16 and 24 h (Wilcoxon: $S = 7.5$, $p = 0.03$, Table 6). When examining individual

Table 5 Aquatic occupational therapy intervention outline

Session components	Example of activities
Warm up social activities	Lining up and taking turns to enter the water Song that facilitated greetings "Face painting" pretend play Choice time—each participant chose from a visual schedule a preferred water play activity Therapeutic techniques included: organizational strategies to provide structure, visual supports, scaffolding, front loading, positive behavior supports including positive feedback, validation, choices, and differential attention
Skill targeting	Each activity was presented in a structured format that started with a song. This allowed for a predictable routine that provided structure to the sessions. Non-verbal or children with limited verbal skills were provided with a visual support. Skills were introduced to the group as a whole and then each participant was given individualized time with the therapist to address the skill at their ability level Activities to elicit breath control: blowing a ping pong ball on the surface of the water, using slightly submerged whistles or straws to teach blowing bubbles on the surface of the water, "blast offs" where the therapist tossed the participant up and down in and out of the water, blowing bubbles in the water with the body in various positions (vertical and horizontal) Activities to elicit pool navigation skills: holding onto the wall of the pool without allowing face to submerge, "walking" on the pool wall using cross over arm movements Activities to elicit propulsion skills: kicking while holding the wall, arm motions while holding the wall, holding a kick board and kicking, holding the therapist's shoulders and alternating arms, kicking with a flotation device Activities to elicit flotation: placing participants back to the wall and learning to use buoyancy to lift legs and stomach to the surface of the water, floating with support at back of head, hips and/or small of back or with a flotation device Activities to elicit changing positions: reaching across the body and grabbing therapist hand to elicit a lateral rotation on the body axis, facilitating at the hips to produce a lateral rotation Activities to elicit exiting the water: at the stairs, at the ladder and at the side of the pool Therapeutic techniques included: sensory enhancement, reduction of sensory input, organizational strategies to provide structure, visual supports, scaffolding, front loading, positive behavior supports including positive feedback, validation, choices, breaks, reinforcement system, differential attention, graded task implementation, augmented feedback, context focused intervention, and physical guidance
Wrap up	"Mystery Hour"—the final task where participants could choose their favorite activity from the session to repeat. This ensured that each child left on a high note Goodbye closing song

swim skills, the participants advanced most consistently with breath control. At all three time points, the participants on average significantly increased their breath control score compared to that of the pre-evaluation [$F_{(1,4)} = 8.9$, $p = 0.0002$, $W = 7.5$, $p = 0.03$ at each time point]. The changing position skill demonstrated significant improvement at 16 and 24 h [$F_{(1,4)} = 7.0$, $p = 0.006$ $W = 7.5$, $p = 0.03$, Table 6]. Propulsion skills improved after 24 h of intervention only [$F_{(1,4)} = 3.1$, $p = 0.06$ $W = 7.5$, $p = 0.03$, Table 6]. Navigation, exiting the pool and back float skills did not improve significantly as measured on the ASC.

Individualized swim goals were formed using goal attainment scaling. The majority of goals fell into three swim categories: breath control, propulsion and back float. The number of goals for each participant and under each category varied however, the baseline for all goals began at a T score of 40 and final testing was completed after 8 h of intervention. Breath control goals (12 total goals for the seven participants) improved at final testing to a T score of 50 and a standard deviation of 10.4 ($W = 14$, $p = 0.016$, Table 7). Propulsion goals (17 total goals for the seven participants) improved at final testing to a T score of 57 and a standard deviation of 14.5 ($W = 55$, $p = 0.0007$). Back float goals (ten total goals for the seven participants) improved at final testing to a T score of 52 and a standard deviation of 13.4 ($W = 26$, $p = 0.006$).

Social skills

Six SSIS forms were completed at baseline and after 8 h of intervention. Analysis of the SSIS scores from baseline to 8 h of intervention revealed no significant difference in social skills ($p = 0.6409$). There was a high rate of non-compliance for completion of the SSIS after 16 and 24 h of intervention, which prevented statistical analysis of the data (only two parents completed the SSIS form after 16 and 24 h of intervention).

Discussion

In this study we investigated the effects of aquatic occupational therapy on water safety and social skills in children with mild to severe ASD between the ages of 3 and 7 years old. The results suggest that group aquatic occupational therapy intervention can improve water safety skills in

Table 6 Changes in aquatic skills checklist scores from pre- to week 8, 16 and 24

Category	Mean ± SE				RM ANOVA	Wilcoxon signed rank
	Pre-intervention (n = 7)	8 Weeks post-intervention (n = 7)	16 Weeks post-intervention (n = 6)	24 Weeks post-intervention (n = 5)		
Total ASC score	13.85 ± 2.97	21.4 ± 3.01	23.5 ± 1.11	26.6 ± 2.65	$F_{(1,4)} = 14.8$ p = 0.0002*	Pre-8 week: W = 7.5, p = 0.03* Pre-16 week: W = 7.5, p = 0.03* Pre-24 week: W = 7.5, p = 0.03*
Navigation	1.7 ± 0.47	2.7 ± 0.28	2.3 ± 0.42	2.6 ± 0.89	$F_{(1,4)} = 1.8$ p = 0.2	Pre-8 week: W = 1.5, p = 0.25 Pre-16 week: W = 0.5, p = 0.5 Pre-24 week: W = 1.5, p = 0.25
Breath control	1.9 ± 0.67	5.0 ± 1.15	6.3 ± 1.02	7.2 ± 1.2	$F_{(1,4)} = 8.9$ p = 0.002*	Pre-8 week: W = 7.5, p = 0.03* Pre-16 week: W = 7.5, p = 0.03* Pre-24 week: W = 7.5, p = 0.03*
Propulsion	1.0 ± 0.65	3.0 ± 0.78	2.5 ± 0.56	3.4 ± 0.88	$F_{(1,4)} = 3.1$ p = 0.06	Pre-8 week: W = 5.0, p = 0.06 Pre-16 week: W = 3.0, p = 0.13 Pre-24 week: W = 7.5, p = 0.03*
Exiting pool	5.8 ± 1.11	6.6 ± 0.97	1.57 ± 0.57	1.28 ± 0.47	$F_{(1,4)} = 1.1$ p = 0.41	Pre-8 week: W 1.5, p = 0.38 Pre-16 week: W = 0.5, p = 0.5 Pre-24 week: W = 3.0, p = 0.13
Back float	1.3 ± 0.47	2.0 ± 0.63	2.6 ± 0.81	1.57 ± 0.81	$F_{(1,4)} = 1.83$ p = 0.03*	Pre-8 week: W=-0.5, p = 0.5 Pre-16 week: W = 1.5, p = 0.25 Pre-24 week: W = 3.0, p = 0.13
Changing positions	1.57 ± 0.81	3.0 ± 0.69	4.5 ± 0.5	4.2 ± 0.49	$F_{(1,4)} = 7.0$ p = 0.006*	Pre-8 week: W = 6.0, p = 0.09 Pre-16 week: W = 7.5, p = 0.03* Pre-24 week: W = 7.5, p = 0.03*

*p < 0.05

children with varying degrees of ASD. The skills most amenable to intervention included breath control, propulsion and changing positions while swimming. We found significant improvements in water safety skills after just 8 h of group therapy. We did not however observe significant changes in social skills as a result of this group aquatic occupational therapy intervention.

Improvements in aquatic skills in past studies range from simple (Rogers et al. 2010; Yanardag et al. 2013) to complex movement patterns (Chu and Pan 2012). Discrete trial training has produced promising results for learning basic movement skills in the water (Rogers et al. 2010; Yanardag et al. 2015; Yilmaz et al. 2010). In the current study, complex movement skills that support water safety were targeted for drowning prevention. Intervention was implemented in a contextually relevant environment (group swim lessons).

In line with previous evidence, this study demonstrates that children with mild ASD can learn swim skills. As

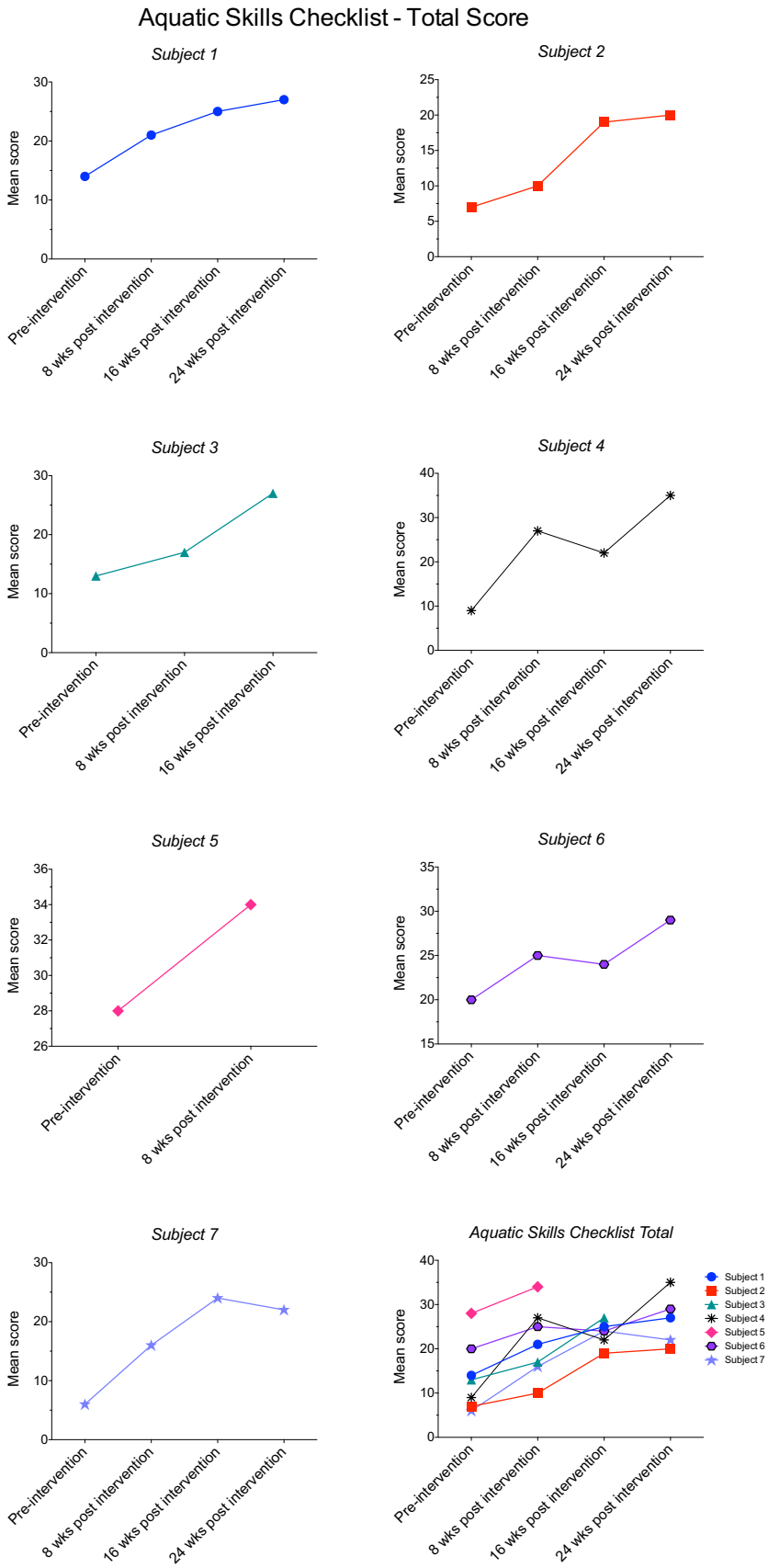

Fig. 1 Changes in aquatic skills by subject. Individual changes for each subject are shown for the aquatic skills checklist total score. Improvements were observed for all subjects regardless of the level of autism (mild: subjects 1 and 5; moderate: subject 6; severe: subjects 2,3,4, and 7). In the final graph all seven subjects were shown in the same graph

Table 7 Changes in goal attainment scaling

Category	Mean difference ± SD	*DF*	Wilcoxon signed rank
Breath control	10.0 ± 10.4	11	W = 14, p = 0.016*
Propulsion	17.1 ± 14.5	16	W = 55, p = 0.0007*
Back float	13.5 ± 13.4	13	W = 26, p = 0.006*

*p < 0.05

stated before, there is a paucity of research investigating the responses of children with moderate to severe ASD to aquatic intervention. The results of this study demonstrate the feasibility of teaching drowning prevention skills to children with mild to severe ASD. One major limitation of this study is the limited sample size. Future studies should recruit a larger sample size of children with severe ASD to determine if these findings can be generalized. There are clinical implications to these findings as well. Therapists working with children with ASD should consider addressing swim skills as part of their usual care. By targeting skills that are particularly salient for drowning prevention, there is an opportunity to meaningfully reduce the risk of drowning for children with ASD.

Studies have varied in the amount of intervention provided to children in order to elicit gains in swim skills. Treatment hours range from as little as 4 h to as many as 32 h (Lawson and Foster 2016; Pan 2010; Chu and Pan 2012). In the present study, we took measurements after 8, 16, and 24 h of intervention. We found that improvements were seen at a significant level after 8 h of intervention. Gains peaked at 16 h of intervention but remained significant after 24 h of intervention. Previous studies have primarily relied on intervention delivered by teachers with education degrees rather than skilled clinical therapists. Our findings agree with Ennis (2011) demonstrating that salient swim skills can be achieved in a relatively short period of time when intervention is provided by a clinical therapist. We provide detailed information on how the skills were addressed during the sessions and the therapeutic techniques utilized to provide a more comprehensive characterization of an aquatic based clinical therapy program to enable replication. Future research should consider implementing the intervention at a higher frequency (daily) for a shorter duration (1–2 weeks). This format is more consistent with community based programs and might elicit quicker motor gains. Moreover, researchers should consider the functional implications of intervention on the participants' ability to access community based swim lessons.

In addition to improving swim skills, studies have suggested that aquatic interventions can improve social skills in children with ASD (Chu and Pan 2012). Our study utilized a group format with structured social opportunities embedded into the weekly routine. In contrast to previous findings, we found no measurable improvements in social skills in our subjects. One limitation we experienced was that the return rate of our outcome measure (SSIS) was low after the first 8 h of intervention, limiting data analysis opportunities. The SSIS is an extensive parent questionnaire and the length may have been prohibitive to eliciting caregiver compliance. Future studies should consider implementing a parent incentive for completing standardized test questionnaires. We also gathered data on communication and communication attempts, as well as social referencing and joint attention. However, when attempting to analyze this data, we identified measurement bias that weakened our findings. Many of the behaviors coded were dependent on uncontrolled environmental factors. Despite extensive training and development of coding rules and parameters, researchers were unable to demonstrate an acceptable interrater reliability when coding social interactions from the videotaped sessions. Future studies should consider gathering audio recordings in water (rather than from a device on deck) and utilizing multiple cameras to improve the ability to code videos for social responsiveness. Gathering this type of direct data would be a more sensitive measure of social skills.

Overall, our findings demonstrate preliminary evidence that children with mild to severe ASD can achieve water safety skills, which are important for drowning prevention. However, there are several limitations that require discussion. The small sample size and lack of socioeconomic data on participants makes generalization of these findings limited. Nevertheless, the inclusion of children with mild to severe ASD does suggest that children of all functioning levels may benefit from aquatic intervention. We also established the feasibility of teaching complex swim skills to children with moderate to severe ASD. A key limitation of this study is the lack of control group or a treatment as usual group. We cannot rule out that some of the swim skills would have been attained spontaneously or as a result of other non-aquatic interventions. Randomized controlled trials of the impact of aquatic occupational therapy on larger samples of children with mild to severe ASD are highly recommended. In addition, future studies should conduct follow up after cessation of intervention to determine skill maintenance.

There is an increasing body of evidence indicating that children with ASD respond positively to aquatic based intervention. Our findings agree with previous researchers demonstrating that children with ASD can learn swim skills. We provide preliminary evidence that children with mild to severe ASD can achieve water safety skills that are important for drowning prevention. Furthermore, we establish response to treatment with as little as 8 h of group intervention, with peak performance observed after 16 h of intervention. Aquatic based occupational therapy is a promising, and

possible life saving intervention for children with varying severity levels of ASD.

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Authors' Contribution MLA conceived of the study, participated in the design and coordination of the study, performed the measurement, participated in the design and interpretation of the data, and drafted the manuscript; SRR participated in the design and coordination of the study and of the data, performed the statistical analysis and helped to draft the manuscript; NRB participated in the design and coordination of the study, performed the measurement, and helped draft the manuscript; ERR participated in the design and interpretation of the data, performed statistical analysis and helped draft the manuscript. All authors read and approved the final manuscript.

Compliance with Ethical Standards

Conflict of interest No conflicts of interest, financial or non-financial, were identified.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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