The effects of aquatic exercise on motor skills and social behaviors in children and adolescents with autism spectrum disorder: A Systematic review

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Systematic Review

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Abstract

Purpose: Children and adolescents with autism spectrum disorder (ASD) have delays in developing motor skills and social behaviors compared to typically developed children. Various exercise program can improve social and motor behaviors of individuals with autism spectrum disorder. There is no consensus among researchers about how aquatic exercise effects of individuals with ASD. The purpose of this study is the comprehensively reviews the impacts of aquatic exercise on motor skills and social behaviors among children and adolescents with ASD.

Methods: This systematic review is based on the PRISMA guidelines. The following criteria was used to determine acceptance into this review: the participants were children and adolescents with ASD, the experimental program was involved aquatic exercise program, and all studies were peer-reviewed English publications from 2002 to 2022.

Results: After applying exclusion criteria, a total of 9 studies were identified. Analysis indicated that various aquatic programs including hydrotherapy and traditional swimming activities can improve motor skill levels and social behaviors in children and adolescents with ASD. Optimal duration of aquatic programs appears to be at least 8 weeks for a minimum of two times per week for 30 minutes per session.

Conclusion: Results of this analysis suggest that physical therapists and physical educators should recommend this intervention when appropriate, and consider developing community-based aquatic exercise programs.

Introduction

Autism spectrum disorder (ASD) is one of the most common neurodevelopmental disabilities, with the most recent data from the U.S. Center for Disease Control and Prevention (CDC) in 2023, the CDC reporting that approximately 1 in 36 children in the U.S. are diagnosed with ASD (Center for Disease Control and Prevention (CDC), 2023). ASD is defined by deficits in social interaction skills, communication (verbal and non-verbal), and restricted repetitive patterns of behavior (Diagnostic and Statistical Manual of Mental Disorders, 2013). Several studies have shown that many children with ASD also display delays or difficulties in gross and fine motor skills (Dewey, 2007; Healy, 2021), dyspraxia, motor stereotypies, and impairment in postural control, motor speed and coordination, balance (Siaperas, 2012). A number of studies have found that physical activity as an intervention can improve motor, behavioral, and social communication skills in individuals with ASD (Hynes, J., & Block, M.E, 2022). In addition, some studies showed the positive influence of regular physical activity on mental and physical health in an individual with ASD (Pusponegoro, 2016). Swimming is the most preferred physical activity for children with ASD (Eversole, 2016) and is as a meaningful activity for all the families and provides opportunity to participate in a typical recreational activity (Mische Lawson, et al., 2019). Benefits of aquatic therapy for children with ASD have been assessed through intervention from clinician and parent
perspectives (Vonder, 2006). A variety of aquatic-based training programs have been found to be beneficial for individuals with autism spectrum disorders (ASD). Swimming activities can be effective training for psychomotor skills and can lead to increasing adaptive behaviors and providing opportunities for social interaction for children with ASD (Marzouki, 2022; Battaglia, 2019). Other studies found aquatics programs can have a positive effect on sleep in children with ASD (Oriel, 2016). Fragala-Pinkham et al reported that 14-week hydrotherapy exercise program improved cardiorespiratory endurance and fitness in children with disabilities include children with ASD (Pinkham, 2008). Pan found hydrotherapy training improved the muscular strength, endurance, self-confidence, social performance, and relationships in children with ASD (Pan, 2011). Marzouki (2022) surveyed of occupational therapists using hydrotherapy to treat children with ASD, and she found both technical and game-based aquatics program were effective in enhancing the attention, muscle strength, balance, toleration of touch, initiation and maintenance of eye contact, and social participation. Additionally, children with ASD and their parents described aquatic therapy, water play skills, and swimming as enjoyable (Eversole, 2016; Vonder, 2006). A study by (Johnson, et al., 2021) assessed parental psychological health and child challenging behaviors before and after a swimming program for children with autism. Results showed improvement in child behaviors and parent perception of general health. Also, parents reported their child had fewer challenging behaviors in the areas of “compliant/ calm,” less “hyperactive,” fewer “self-injury/stereotypies,” improved “overly sensitive,” and fewer conduct problems (Johnson, et al., 2020).

Swimming also benefits leisure engagement, which is a common concern with this population (Stanish, 2017). It can be assumed that the positive effects of different aquatic programs in children with ASD are realized thanks to the physical properties of water (thrust force, hydrostatic pressure and viscosity). The mentioned characteristics achieve minimal pressure on the joints, enable easier movement and provide an excellent opportunity for developing muscle strength, cardiorespiratory endurance and flexibility during swimming itself, i.e. without changing the functional pattern of movement (Dunlap, 2009). Aquatic activities also develop motor control and body awareness, including improving coordination of arm and leg movements through maintaining floating balance and breathing control (Dunlap, 2009). Children with movement difficulties experience more success in attaining movement skills in an aquatic environment with respect to a land-based setting because of the buoyancy of the water, and of the decreased effects of gravity, which may allow an individual to exercise motor skills with fewer body constraints (Pan, 2011).

There have been three systematic review on the effects of aquatic activities on children with ASD (Aleksandrovic, Jorgic, Block, & Jovanovic, 2016; Mortimer, Privopoulos, & Kumar, 2014; Murphy, & Hennebach, 2020). However, these studies included all studies, regardless of their quality and risk of bias including case studies with only one subject and studies without a control group. Therefore, the purpose of this review is examine experimental studies that examined the effects of aquatics programs in children with ASD. A specific question is proposed: ‘Can aquatic programs be effective in improving motor and social skills in children and adolescents with ASD? As secondary objectives, we aim to (1) explore which exercise parameters (intensity, type and modality, frequency of training, duration, etc.) may be more effective to improve the aforementioned outcomes in this population.

**Methods**
This review was conducted and reported in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (see Fig. 1). The protocol of the systematic review was registered prospectively in the PROSPERO International Prospective Register of Systematic Reviews (CRD42021236555) and can be consulted online. No changes to the protocol were made after registration.

**Population**

Studies were included if the participants were aged 5 – 15 years, of either sex, and diagnosed with Autism spectrum disorders. Exposure to prior aquatic experience or other prior interventions did not result in any exclusion of participants.

**Intervention**

Studies were included if the intervention described a hydrotherapy program, aquatic exercise, swimming and other water sports, water play at Least 4 weeks Program. with or without follow up.

**Search Strategy**

This study utilized a systematic qualitative review of the literature, with the aim of the effects of aquatic exercise on motor skills and social behavior in children and adolescents with ASD. The researchers examined seven electronic databases. The databases were used for conducting the search included: PubMed, Cochrane, Scopus, Embase, Web of science, Psycinfo, EBSCO HOST database for articles published 2002 up to October 2022. The search was limited to English language.

**Study Design**


A total of 2705 articles were found across the databases. After duplicates were removed, 780 articles remained. Potential studies were identified by evaluating the title and abstract to determine their appropriateness, following the Population, Intervention, Comparator and Outcome (PICO) criteria (see Table 1). The relevant studies were independently reviewed and were screened in full text by the two reviewers based on inclusion and exclusion criteria.

**Eligibility Criteria**
To retrieve relevant papers, the search organized using a PICO strategy (acronym for Patient, Intervention, Comparison and Outcome).

- Participant group of research should be consisted of individual with autism spectrum disorder (ASD), Children and adolescents, men and women 5–15 years old.
- The intervention was any type of aquatic therapeutic exercise. At least 4 weeks and 4 participants in each group.
- The articles needed to include randomized control trials or nonrandomized control with assessments trough Functional (physical, motor, social) tests, interview and questionnaire
- The papers that explicitly planned to identify the effects of aquatic exercise (compared to participants in control group)
- Original article (No systematic review or scoping review or opinion editorials or editorial comments or case report or letter to the editor or short research communications).
- Quantitative and quantitative research
- They had to be written in the English and published in peer-reviewed journals, as a full article
- They had to be published from January 1, 2002 to August 2022.
- Articles published in English

**Exclusion Criteria**

We will exclude non–peer-reviewed articles as well as dissertations, conference abstracts, unpublished data and manuscripts, and systematic review and meta-analysis and case–control studies. Additionally, we will exclude training program less than 4 weeks, and studies that have no control group, and studies in which there were less than four persons in the experimental and control group.

**Outcome measures**

Studies were included if they utilized outcome measures that assessed motor skills and social behaviors through questionnaire or observation or assessment. The literature search yielded seven citations which were screened for eligibility. 2705 studies were identified using databases and 63 additional studies were identified from other references. 780 studies remained after duplicates were removed using EndNote X9.

An initial analysis was performed based on the title and abstract. When the title and abstract were unclear, the full text was read. The full texts of articles considered possibly relevant were analyzed to determine whether the articles met the eligibility criteria. After screening title and abstracts, 467 were removed due to

the lack of relevance, written in a language other than English, and/or were reviews of literaturea and not stu actual research studies. Finally, we identified 29 studies eligible for full-text screening. 20 of which were excluded because they either had no clear intervention (n = 4), the intervention lasted less than less than four weeks (n = 5), there was no control group (n = 6), outcome measures did not match the targeted
outcomes in this review (n = 6), or were case studies (n = 3). Thus, nine studies were included in the final examination for this systematic review. A summary of search strategy is outlined in Fig. 1.

**Data Extraction**

The data was extracted independently by the three reviewers for accuracy disagreements were resolved through consulting and discussions where needed. Data were collated into excel spread sheets, including information related to: study design; participants’ information (age, sex, and diagnosis); intervention components (duration; time and frequency of the intervention); experimental design and method randomization; outcome measures; statistical analyses; and the results of pre- and post-analysis or other appropriate analysis. The collected data were compared, but due to the small number of studies and variability in the outcome measures, a meta-analysis was not appropriate. Therefore, a systematic review analysis was performed. Study characteristics showed in Table 2.
Table 2  
Characteristics of the included studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size</th>
<th>Diagnostic criteria</th>
<th>Program design</th>
<th>Aquatic interventions</th>
<th>Outcomes</th>
<th>Key findings</th>
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<tbody>
<tr>
<td>Pan (2010)</td>
<td>N = 16</td>
<td>High-functioning ASD (n = 8)</td>
<td>EG1 &amp; EG2: DI – 10 weeks (10 weeks aquatic exercise, 10 weeks treatment reversed, and 1 week transition). WF – 2 times per week (20 sessions) ISD – 90 min.</td>
<td>EG1 &amp; EG2: aquatic program consisted of Social and warm-up activities, one-to-two small group instruction, whole group swimming games and cool-down activities</td>
<td>HAAR, SSBS–2</td>
<td>EG 1 showed ↑ in HAAR, SSBS–2: Sig.↑ EG1 between T1 and T2; SSBS–2: ↑ EG1 between T1 and T2; EG2 between T2 and T3 (not in all subtests). Results indicate that the aquatic exercise program improved aquatic skills in the participants, and holds potential for social improvement</td>
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<td>2. Pan (2011)</td>
<td>N = 30</td>
<td>ASD (n = 15)</td>
<td>EG: DI – 32 weeks, WF – 2 times per week (28 sessions) ISD – 60 min</td>
<td>Goals were individually determined to meet the specific needs of each participant in cooperation with the consultation of therapists. The HAAR (Humphries, 2008), includes five stages of aquatic skills, 10 min. warm up activities, 35 min. swimming exercises, 15 min. group games, 10 min. cool down activities</td>
<td>Curl-up, Sit and reach test, HAAR</td>
<td>At T2 measurement, findings indicated that children with ASD in group EG had significantly higher scores than those of children with ASD in CG 30 s curl-ups, aquatic skills at stages IV, V. Children with ASD in EG also had ↑ results than those of children in group CG on 30 s curl-ups, 60 s curl-ups, aquatic skills at stages II, IV &amp; V. There were Ø in flexibility</td>
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<td>3. Fragala-Pinkham et al. (2011)</td>
<td>N = 12</td>
<td>AS (n = 7)</td>
<td>EG: DI – 14 weeks WF – 2 time per week (28 sessions) ISD- 40 min.</td>
<td>EG: programme (swimming laps, shallow water running, jumping in water, front crawl, back crawl, breast stroke)</td>
<td>SCS, YMCA, HMW/R, M-PEDI, Modified curl-ups &amp; modified push-ups</td>
<td>No Ø between EG and CG group for any of the outcomes. Authors noted improvements in swimming skills among EG.</td>
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<tr>
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<td>4. Chu, &amp; Pan (2012)</td>
<td>N = 21</td>
<td>ASD (n = 21)</td>
<td>EG1-PG, EG2-SG &amp; CG:</td>
<td>Aquatic program consists of teacher-directed and the peer/sibling assisted Conditions in EG1-PG, EG2-SG; no specific peer-assisted interactions in CG</td>
<td>HAAR, CEPI-PE</td>
<td>All groups showed ↑ in areas 2, 3, 4, and 5 in HAAR. No Ø between groups. PG and SG of children with ASD showed ↑ on physical and social interactions with their TD peers/siblings; PG and SG of children with ASD showed ↑ on physical interactions with their TD peers/siblings and social interactions with their teachers and other children with ASD compared to CG</td>
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<tr>
<td></td>
<td>EG1 = 7 sibling-assisted (SG), EG2 = 7 peer-assisted (PG)</td>
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<td>DI -16 weeks</td>
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<td></td>
<td>CG = 7</td>
<td>Gender: M &amp; F,</td>
<td>WF – 2 times per week (32 sessions)</td>
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<td></td>
<td>Age: 7–12</td>
<td>ISD – 60 min.</td>
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<td>5. Caputo et al (2018)</td>
<td>N = 26</td>
<td>Autism (n = 21)</td>
<td>EG: DI- 10 months</td>
<td>CI-MAT aquatic program consisted of</td>
<td>CARS, VABS, HAAR</td>
<td>CARS - ↑ in EG regarding CG in 3 items: Emotional Response, Adaptation to Change, &amp; on Activity Level, ↑ in EG between T1 and T2 in all items with the exception of Nonverbal Communication and of General Impression, VABS - ↑ in EG regarding CG only in Daily living, Sig ↑ in EG between T1 and T2 in all subscales, HAAR - ↑ in EG between T1 and T2</td>
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<td></td>
<td>EG = 13, 8.3 ± 2.3</td>
<td>ASD (n = 5)</td>
<td>WF – 3 times per week (96 sessions)</td>
<td>I-Emotional Adaptation, II-swimming adaptation, III-social integration mainly aerobic training (for all the three phases) and some resistance training</td>
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<td></td>
<td>CG = 13, 7.7 ± 2</td>
<td>Gender: M &amp; F;</td>
<td>ISD – 45 min.</td>
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<td>CG: maintained their usual PA</td>
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<table>
<thead>
<tr>
<th>Study</th>
<th>Sample size (mean ± SD)</th>
<th>Diagnostic criteria</th>
<th>Program design</th>
<th>Aquatic interventions</th>
<th>Outcomes</th>
<th>Key findings</th>
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<tr>
<td>6. Zanobini, &amp; Solari (2019)</td>
<td>N = 25</td>
<td>ASD (n = 17)</td>
<td>EG: D1 – 24 weeks (12 sessions)</td>
<td>EG Activities:</td>
<td>ABC, SRS</td>
<td>Regarding aquatic skills, EG showed ↓ of symptoms in almost all the subscales of the ABC (i.e., Sensory, Social Relating, Body and object use, and Social and self-help and total score). Also, children showed a ↓ in SRS subscale (severity of symptoms in SC and autistic mannerism) and only the improvement in SC and likewise, positive changes in aquatic skills were maintained 6 months after the end of the program. Also, tendency to respond to facial affect, eye contact, imitation, and touch improved.</td>
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<td>EG = 13, 68.23 ± 15.18 months, PDD (n = 4)</td>
<td>MDD(n = 4)</td>
<td>WF - once every 2 weeks, ISD - 90 min; CG = 24 weeks, WF – 1 time per week; ISD - No info.</td>
<td>1. Familiarity with the environment, 2. Initial water activities 3. Game experience, with various tools, in the medium pool, 4. Inclusion in the classmates’ group, 5. Activities aimed at promoting the autonomy of the child, 6. Acquisition of swimming technique, 7. Swimming activities</td>
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<td>CG = 12, 65.08 ± 18.47 months, Gender - M &amp; F</td>
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<td>CG Activities: music therapy or different kind of sports: soccer, skiing or rugby</td>
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<td>7. Mills et al. (2020)</td>
<td>N = 8</td>
<td>ASD (n = 8)</td>
<td>EG1 &amp; EG2:</td>
<td>Aquatic program consists of a variety of activities targeting, swimming balance, eye-hand coordination, and cognitive tasks</td>
<td>CBCL</td>
<td>EG1 &amp; EG2 showed ↑ in 4 subscales and total score (CBCL). Authors state that aquatic exercise may ↑ behaviours impacting mental health and well-being of children with ASD and could be considered a therapy option</td>
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<td>EG1 = 4,</td>
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<td>DI - 8 weeks (4 weeks PA + 4 weeks control)</td>
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<td>EG2 = 4</td>
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<td>WF: - 1 time per week (4 sessions)</td>
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<td>8.72 ± 1.99</td>
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<td>ISD - 45 min.</td>
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<td>Gender: M &amp; F</td>
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<td>8. Ansari et al. (2020)</td>
<td>N = 30</td>
<td>ASD (n = 10)</td>
<td>EG &amp; EGK:</td>
<td>EG: Aquatic program consisted of a pediatric aquatic exercise program combined with the Hallywick method (orientation training, basic swimming skills and free swim) while EGK did kata exercises and GG did none</td>
<td>MST, HTWT</td>
<td>↑ in MST &amp; HTWT in both groups compared to CG. The results showed that both interventions had a significant effect on balance abilities, even the EGK (kata practice group) had better ↑. Due to importance of balance in daily functions, swimming exercises could be considered as valuable intervention added to autism's daily programs</td>
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<td>EG = 10,</td>
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<td>DI - 10 weeks</td>
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<td></td>
<td>EGK = 10,</td>
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<td>WF - 2 times per week (20 sessions)</td>
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<td>CG = 10,</td>
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<td>ISD - 60 min.</td>
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<td>Gender: M</td>
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<td>AGE: 8 – 14</td>
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<td>Study</td>
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<td>9. Marzouki et al. (2022)</td>
<td>N = 22</td>
<td>ASD (n = 22)</td>
<td>EG1 &amp; EG2: DI – 8 weeks, WF – 2 time per week (16 sessions)</td>
<td>EG1: Technical training protocol was based on the Halliwick Method and the foundational swimming skills. EG2: The game-based training protocol. CG: did not attend any additional exercise training in or out of school during the intervention period.</td>
<td>TGMD-2, GARS-2, ERC</td>
<td>↑ in EG1 &amp; EG2 in TGMD-2 compared to CG in regard to T1. Also, EG1 &amp; EG2 showed ↑ results in GARS-2 in regards to T1. Furthermore, both EG1 &amp; EG2 showed ↑ in ERC in regards to T1.</td>
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</table>

**Legend:** ASD – Autism spectrum disorder; EG – experimental group; CG – control group; M – male; F – female; PDD - Pervasive developmental disorder; MDD - Multisystem developmental disorder; WF – weekly frequency; DI - Duration of intervention; ISD – individual session duration; ABC - The Autism Behavior Checklist; SRS - The Social Responsiveness Scale; ↓ - significant decrease; ↑ - significant increase; SC – social communication; Ø – no changes; TGMD-2 - Assessment of Gross Motor Skills; GARS-2 - Assessment of Stereotyped Behavior; ERC - Assessment of Emotional Regulation; T1- baseline measurement time; PA – physical activity; TP – training program; CSHQ - Children's Sleep Habits Questionnaire for sleep habits; IL-1 IL-1ß - serum levels of Interleukin-1 beta; TNF- α - Tumor necrosis factor- α; AS - Asperger syndrome; PDD-NOS-pervasive developmental disorder–not otherwise specified; SCS - Swimming Classification Scale; HMW/R test - half mile walk/run; M-PEDI - Evaluation of Disability Inventory Mobility scale; YMCA - Water Skills Checklist; HAAR - Humphries Assessment of Aquatic Readiness; SSBS–2 - School Social Behavior Scales; CEPI-PE - Computerized Evaluation Protocol of Interactions in Physical Education; CBCL - Child Behavior Checklist; MST - Modified Stork test; HTWT - Heel to toe walking test; TD – typical development; CARS - The Childhood Autism Rating Scale; VABS - Vineland Adaptive Behavior Scales.
The Cochrane Risk of Bias tool (RoB2) was used for assessing the risk of bias in randomized trials. The tool consists of five domains, each focusing on a different aspect of the trial. Each domain has several signaling questions, and an algorithm is then used to judge the methodological quality of the trial, based on the answers. Categories for each question were classified as low, some concerns, or high risk of bias (Sterne et al., 2019). The current review was designed in accordance with the preferred reporting items for systematic reviews and meta-analyses (Liberati et al., 2009), and the Cochrane Handbook for Systematic Reviews of Interventions (Higgins & Altman, 2008). Two reviewers examined risk of bias independently, and when disagreements occurred, a third reviewer examined it again. If any item was unclear, we contacted the authors by email to clarify the issue. Results of the risk of bias assessment are presented in Fig. 2. Results of quality assessment showed: all studies (nine articles) had adequate internal validity and were categorized as a low risk of bias, and all nice were were included in our data extraction and synthesis of results.

**Results and Discussion**

Present systematic review showed that the aquatic exercise intervention programs were effective in improving motor skills and social behavior in children and adolescents with ASD. Therefore, aquatic exercise and can be recommended as an effective intervention for children and adolescents with ASD. Literature on the effects of exercise interventions in individuals with ASD showed that physical activity is useful for improving motor outcomes and functional abilities (Bremer et al. 2015; Hynes & Block, 2022), and also suggested that it can be helpful for improving behavioral, cognitive, and social difficulties (Macdonald et al. 2012; Ward et al. 2013). As specifically regards the aquatic therapy, several findings demonstrated improved motor skills and physical fitness of individuals with ASD (Fragala-Pinkham et al. 2011).

**Participants**

Diagnosis of ASD was reached after a multidisciplinary assessment by a neuropsychiatrist and a specialized clinical psychologist in the evaluation of individuals with neurodevelopmental disorders according to DSM-V criteria. In the study by (Caputo, 2018), the Clinical diagnosis was validated by the Autism Diagnostic Interview-Revised (ADI-R; Lord et al. 1994) and the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999). In the study by Zanobini, experimental group included nine participants received the diagnosis of ASD, three participants a diagnosis of multisystem developmental disorder, and one diagnosed with erasive developmental disorder. In the study by Fragala-Pinkham (2022), the children's diagnoses included autism spectrum disorder, myelomeningocele, cerebral palsy, or other developmental disability. None of the participants had evidence of severe sensory/motor deficits or of known co-morbid medical conditions. In the study by Zanobini, diagnostics criteria of the ICD-10, DSM-IV, DSM 5 or DC: 0–3 (Zero to Three Diagnostic Classifications of Mental Health and Developmental Disorders of Infancy and Early Childhood 1994) were used. Moreover, the Autism Behavior Checklist (ABC: Krug et al. 1978) was administered to every child to confirm clinical diagnosis. The total number of participants for all the studies combined was 254. The number of participants varied from study to study.
The fewest number of participants was the study by Mills and colleagues (2020) with eight participants (four children in each group), and the largest number of participants was in the study by Ansari and colleagues (2020) and Pan (2011) with 30 participants. The largest number of groups was in the study by Chu and colleagues (2012) with three groups (two experimental divided to peer-assisted group and sibling-assisted group and one control group).

**Duration of aquatic program**

Program lasted from eight weeks in the study by Mills et al (2020) and Marzouki et al, (2022) to eight months (32 weeks) in the study by Pan (2011) and ten months in the study by Caputo and colleagues (2018). Frequency of exercise ranged from once every two weeks in the study by Zanobini and Solari (2019) and once weekly in the studies by Captu (2018) and Mills (2020) to twice per week in the studies by Pan (2010), Pinkham (2011), Ansari (202), Chu (2012) and Marzouki (2022). The smallest duration of each aquatic training session was 30 minutes in the study by Zanobini & Solari (2019) and Chia-Hua Chu & Pan (2012) while the maximum duration was 90 minutes in the study by Pan (2010). Given that the exercise programs were of different durations; it can be said that the duration of the program does not play a significant role in determining the effects on motor and social behaviors.

Observing the temporal rationalization of the exercise program, the obtained results indicate that successful changes in aquatic skills in children with ASD can be achieved with programs that last from as little as 10 to 14 weeks with a frequency of 2 times a week and the duration of an individual lesson of 40–45, 60 or 90 minutes. The specificity of conducting activities in the water for children with ASD requires an approach in practicing 1-on-1 or in smaller groups in the ratio of one instructor to two to three children with ASD, which is demanding in terms of economy. However, positive results of the research indicate that the improvement of aquatic skills can also be achieved when in a 1-to-1 ratio when with children with ASD are paired with their siblings or peers (Chu & Pan 2012; Pan 2011).

**Structure of the aquatic session**

Aquatic programs have consisted of different aquatic exercise and aquatic activities. The structure of the aquatic sessions in the study by Caputo, et al. (2018) began with a one-on-one instructor-to-child ratio with later phases utilizing small groups of four to six children with a one-to-three expert-to-child ratio. In the study by Zanobini & Solari (2019), despite the one to one nature of the educator-child relationship, the activity was carried out in a mainstream context during school time and also involved typical children of the classes. Gradually, the children ASD were included in small groups of peers. Fragala-Pinkham and colleagues (2011), used group aquatic aerobic exercise, while the study by Chu & Pan (2012) used three instructional conditions (teacher-directed, peer/sibling-assisted, and voluntary support). The study by Pan (2010), included one-to-two small group instruction in which one child with ASD and his sibling were assigned to a trained instructor, and then later they attended in whole group games/activities. In the study by Chu (2012) the aquatic training consisted of teacher directed assistance along with peer and sibling assistance. The hydrotherapy sessions in the study by Mills, et al. (2020), began with a one-to-one instructor-to-child ratio, but later phases of the study focused on “social integration”, where the child with
ASD participated in general group-swimming activities. At this stage, the instructor-to-child ratio was one-to-three. Only one study Zanobini & Solari, 2019) included a follow-up session after a 6-month period of interruption of the program.

**Outcomes measurements (Study Variables and Measuring Instruments)**

The aquatic exercise programs used in the analyzed studies were aimed at increasing the motor and social skills of children with ASD. Outcome measures differed in each program. In the study by Caputo et al. (2018), children received a pretreatment and post treatment assessment using the Vineland Adaptive Behavior Scales for measuring functional adaptation, emotional response, adaptation to change and on activity level, as well as the the Humphries' Assessment of Aquatic Readiness (HAARS) to measure aquatic skills. Zanobini and et al (2019), the Childhood Autism Rating Scale (CARS; Schopler et al.1993), Vineland Adaptive Behavior Scales (VABS; Sparrow et al. 1984), and the Humphries' Assessment of Aquatic Readiness (HAAR; Humphries 2008). Zanobini and Solari (2019) used the Autism Behavior Checklist (ABC, Krug et al. 1978), the Social Responsiveness Scale (SRS, Constantino and Gruber 2005) and the Humphries' Assessment of Aquatic Readiness (HAAR, Humphries 2008) used. The study by Mills and colleagues (2020) utilized the Child Behavior Checklist (CBCL) to measure behavior changes impacting mental health and well-being, and the study by Marzouki (2022) used the Test of Gross Motor Development, the stereotypy subscale of the Gilliam Autism Rating Scale, and the Emotion Regulation Checklist.

**Effects of Aquatic Programs on Social and Behavioral Changes**

In terms of specific findings, Mills, et al. (2020) found that hydrotherapy intervention significantly improved externalizing and internalizing problems including anxiety, depression, and attention problems. They suggested the hydrotherapy may enhance behaviors impacting mental health and well-being of children with ASD and can be considered a useful treatment option. Zanobini and Solari (2019) found their experimental group showed significantly reduced severity of symptoms in sensory issues and social relating, body and object use, social and self-help, and improvement in autistic mannerism and social motivation. The follow-up results six-months after the end of the program also showed positive changes in aquatic and social communication skills were maintained. In the study by Hamza Marzouki and colleagues (2022), children with ASD were randomly assigned to either a technical aquatic program or a game-based aquatic program showed significant improvement in gross motor skills and stereotypy behavior compared to the control group. Also, a small pre-post change effect in emotion functioning was found in all groups. No significant differences were observed between the experimental groups in all assessed variables.

Pan (2010), examined the effects of a 10 week water exercise swimming program on aquatic skills and social behaviors of 16 boys with ASD. The 10-week intervention consisted of 20 sessions (two sessions per week, 90 minutes per session). Each session was divided into four categories: (A) social and floor
warm-up activities, (B) one-to-two small group instruction, (C) whole group games/activities, and (D) cool-down activities. Improvements were seen in aquatic skills for both groups after participating in the program. Fragala-Pinkham, et al. (2022), investigated the effects of a group swimming and aquatic exercise program for 12 children with ASD. The program was held twice per week for 40 minutes per session. The pool session consisted of 3 to 5 minutes of warming up, 20 to 30 minutes of aerobic exercise, 5 to 10 minutes of strength training, and 3 to 5 minutes of cool-down and stretching. The strengthening component consisted of exercises using bar bells, aquatic noodles, and water resistance. Results showed significant improvements in the half-mile walk/run test of cardiorespiratory endurance, but not for secondary outcomes of strength or motor skills after participation in the aquatic exercise.

Chu and Pan (2012), investigated the effects of a peer-assisted (PG), sibling-assisted (SG) aquatics program children with ASD. The main findings were that (a) peer-assisted and sibling-assisted groups of children with ASD showed significantly more improvement on physical and social interactions compared to a control group, (b) PG and SG children with ASD showed significantly more improvement on physical and social interactions with their peers/siblings without ASD compared to the control group, and (c) all children with ASD and their peers/siblings without ASD significantly increased their aquatic skills after the program. Soleyman Ansari and et al. (2020), investigated the effects of aquatic versus kata techniques training on static and dynamic balance in children with ASD. Participants practiced for 10 weeks, 2 sessions of 60 min per week. A 10 week aquatic exercise program consisting of 20 sessions (2 sessions per week; 60-min per session). Results showed that both interventions had a significant effect on balance abilities among children with ASD.Caputo et al (2018), investigated that effectiveness of a multisystem aquatic therapy on behavioral, emotional, social and swimming skills of children with ASD. Multisystem aquatic therapy was divided in three phases (emotional adaptation, swimming adaptation, and social integration) implemented in a 10-months-program showed significant improvements in functional adaptation, emotional response, adaptation to change, on activity level, and swimming skills when compared to a control group.

**Effects of Aquatic Programs on Motor skills**

Motor skill has been identified as one of the important areas of a child’s development (Hazel, 2018), and (Mohd-Nordin et al, 2021) showed that children with ASD had delays in developing motor skills compared to typically developed children. Regarding swimming, Prupas et al. (2006) suggested that the ability to swim in children with ASD is less compromised than other physical skills. Therefore, swimming can contribute to improving the motor performance of this population through the possibility of performing a variety of motor skills in an aquatic setting with or without assisted active movement. It has been reported that swimming can be effective in improving motor skills among typically developed children (Leo et al., 2022). There is also evidence that swimming programs can have a similar positive effect among people with ASD (Yilmaz et al., 2004; Pan (2011, 2010; Marzouki et al., 2022). In our systematic review, of the 11 analyzed studies, seven examined the effects of aquatic activity on motor skills and motor abilities (Pan, 2001, 2010; Fragala-Pinkham et al., 2011; Chu & Pan, 2012; Caputo et al, 2018; Ansari et al., 2020; Marzouki et al. (2022). By motor abilities we meant the effects of aquatic training on
elements of physical fitness, such as muscle strength and endurance, flexibility, balance, cardiorespiratory fitness (Gibson, 2019). By motor skills we mean achieved training effects on locomotor and object control skills (Williams & Monsma, 2017). We also included the swimming skills as a part of motor skills, considering that it also involves specific movements of the body's muscles to perform a certain task. In five studies, the effects of the aquatic exercise swimming program on swimming skills were investigated. Among the tests for the assessment of swimming skills, the most common was the HAAR test (Pan, 2010; Pan, 2011; Chu & Pan, 2012; Caputo et al, 2018), while Fragala-Pinkham et al. (2011) used the YMCA and SCS swimming assessments. In the first three mentioned studies (Pan, 2010; Pan, 2011; Chu & Pan, 2012), aquatic exercise swimming programs were designed based on the used HAAR program, the basis of which is the Halliwick method (Martin, 1981). The exercise programs themselves included the use of the TEACCH model (Virues-Ortega, 2013), in terms of the organization of the physical environment (e.g. establish clear boundary markings to help children know where they may and may not go) and visual schedules and work systems (e.g. a board with pictures and words to describe the routine and swimming activity). All four studies, positive effects were achieved in terms of a significant improvement in swimming abilities (mental adjustment, introduction to water environment, rotations, balance and control and independent movement in water). For example, Pan (2010) found significant improvements in HAAR test scores (p < 0.01) between initial and final testing after 10 weeks of the program. Also, it is significant that the acquired aquatic skills were maintained in the follow-up period after 10 weeks. Similar research by Pan (2011) found significant changes in stage IV and V of the HAAR test compared to the control group (p < 0.05) after 14 weeks of exercise. As with the previous research, the obtained improvements in aquatic skills remained unchanged in the follow-up period after 14 weeks without the activity of the experimental group.

The effects of the aquatic program on motor skills and abilities were investigated in ASD children who had mild or high functioning autism or Asperger syndrome (Pan, 2010; Pan, 2011; Pinkham et al., 2011; Chu & Pan, 2012), or they have mild to moderate autism (Ansari et al., 2020; Marzouki et al., 2022). This indicates that the effects of aquatic activities on children with ASD who have severe autism remain unexplored. Since the basis of aquatic exercise in the aforementioned studies was the Halliwick method, it can be assumed that this method is also a safe and efficient program for children with ASD, as according to (Vodakova, 2022) it is safe for people of all ages and with many types of disabilities. The positive effects of the Halliwick method are realized thanks to the fact that this method represents a psycho-sensory motor learning process that is effective for people and children who need active motor learning or relearning in a “slow” medium that limits mechanical influences (Jorgic, et al, 2014).

In terms of physical fitness, the effects of aquatics programs on cardiorespiratory endurance, muscle strength, and flexibility have been investigated in three studies (Pan, 2011; Fragala-Pinkham et al., 2011; Ansari et al., 2020). In Pan's (2011) study, a statistically significant increase was achieved in muscle strength as measured by curl-ups (30s and 60s tests), (p < 0.05). In contrast, Fragala-Pinkham, et al. (2011) did not find significant changes in muscle strength testing with modified curl-up and isometric push-up tests. Fragala-Pinham and colleagues suggested the reason for no statistical significant differences in strength measures in their study was their small sample size. In the research (Ansari et al.,
a significant difference was found between the aquatic group and the control group in static and dynamic balance ($p = 0.001$). Given that there is a significant correlation between dynamic balance and core strength in children with ASD (Salar, et al., 2014), the obtained results (Ansari et al., 2020) are significant from the aspect that balance in these children can be developed with aquatic exercise. The effects of aquatic exercise programs on motor skills were investigated in only two studies (Fragala-Pinkham, et al., 2011; Marzouki, et al., 2022). In the first study, there were no statistically significant changes in motor skills measured by the M-PEDI test with a low (0.27) effect size. Marzouki et al. (2022) assessed motor skills using the Test of Gross Motor Development-2 (TGMD-2). Results showed statistically significant positive changes in both experimental groups in locomotor and object control skills in relation to time as well as in relation to the control group. The first experimental group applied the technical aquatic activities program, and the second experimental group used a game-based aquatic activities program. When it comes to the effects of aquatic programs on the development of physical fitness and motor skills (excluding aquatic skills), no conclusions can be drawn about the positive impact of the aquatic exercise program based on the limited reviewed research. The reasons are primarily a small number of high-quality research in terms of low risk of BIAS and the existence of several experimental and control groups. In this systematic review, only four studies were singled out (Pan, 2011; Fragala-Pinkham et al., 2011; Ansari et al., 2020; Marzouki et al., 2022). Another reason is the contradictory results. Some of the research a significant change was achieved, while in others there was no change in the tested fitness and motor skills. Consistent with previous studies, our findings confirm that children with different levels of autism can demonstrate improvement in motor skills in an aquatic environment and can learn to swim (Yanardag et al. 2013; Aleksandrovic, et al., 2015).

**Effects of Aquatic exercise on social skills**

Yilmaz and colleagues (2004), found a reduction in stereotypic movements. Parents report skills developed within the context of swimming carry over to other aspects of a child's life, such as decreased stereotypic movements (YILMAZ, 2004). Chu and Pan (2012) found decreased physical interactions with teachers in children with ASD after a 12-weeks of aquatic training. The authors suggested that although such a result may appear negative at a first sight it could be interpreted as a positive change of the child with autism who would be less reliant on adult interaction and more willing to interact with her/his peers (Chu & Pan, 2012). Vonder Hulls, et. Al., (2006) discussed similar findings in their research, suggesting that a decrease in children with ASDs asking teachers for help could be interpreted positively as a sign that the child is gaining confidence and independence, rather than as diminishing interactions. The study by Ennis (2011) implemented a 10-week water program on children with ASD, with results showing improvements in social skills and interaction with peers and smaller changes in emotional and school functioning after aquatic therapy intervention (Ennis, 2011). The effect of the aquatic program on behavioral and social skills in the study by Pan, 2010 evidenced in decreased antisocial behavior problems, but not in increased social competence behaviors. In their study, some strategies were implemented with the goal of making the social interaction including encouraging children to seek assistance from each other, facilitating interactions during transitions and during group games and
activities, lining up for a turn, and even non-instructional socialization. In addition, parents reported the program increased sense of accomplishment and self-worth (Pan, 2010).

Regarding social skills, the aquatic skills, aquatic programs at least eight weeks in duration can effect improvement in aquatic skills in children with ASD. There was an improvement in aquatic skills and gross motor skills after the seven weeks Halliwick Method on aquatic skills (Vodakova, et al., 2022). Video-based instruction for swimming training is recommended to have effects on improving movement difficulties children with ASD (Yanardag, 2013).

**Strengths and limitations**

There are several strengths to this study. To the best of our knowledge, this is the first systematic review that evaluates the available evidence from published randomized control trials on the effectiveness of aquatic exercises on motor skills and social behaviors among children and adolescents with autism spectrum disorder. Strengths of this systematic review included incorporating both qualitative and quantitative evidence synthesis, following PRISMA guidelines. Two reviewers independently and rigorously reviewed and extracted data to minimize the chance of error. In addition, validated assessment tools were used to the risk of bias with validated assessment tools. There were no articles that showed a high risk of bias. However, our systematic review has some limitations. For example, only English-language articles were considered, which limits our findings by potentially excluding relevant articles. we were not able to calculate the effect sizes for studies. In addition, given the diversity of the outcome measures used and heterogeneity in sampling and interventions, a direct comparison of results between studies was not possible. Only one of the included studies examined the post-intervention follow up. We suggest to long-term follow-up undertaken, to capture the sustainability of outcomes. Future studies is needed to the explore the most efficient way for aquatic training and to focus on compare individualized and group aquatic and family-based program setting. Also, future studies could address the effect of age, the intensity of intervention, class size, and student-teacher ratio, and the feasibility of some adapted equipment for applying aquatic exercise for children and adolescents with autism spectrum.

**Conclusion**

The aim of this systematic review was to determine the effects, that is, the justification of the application of different aquatic exercise programs on the development of motor and social skills in children with ASD. With regard to development of aquatic skills as part of motor skills, it can be concluded that aquatic exercise programs can successfully develop these skills in children with ASD. A Successful significant effect was achieved through the application of different aquatic programs in terms of content of program activities and training volume (duration of individual training, weekly frequency and total duration of the program). At the same time, it should be emphasized that statistically significant improvements in aquatic skills were achieved in children with mild or high-functioning autism or Asperger’s syndrome, because such children made up the sample of subjects. In this sense, it is necessary to conduct new research in which the sample of subjects would be children with severe autism disorders.
When it comes to the effects of the aquatic exercise program on the development of motor skills, which are realized on dry land and which concern various locomotor activities, there is a lack of evidence because of a small number of studies. With regards to physical fitness, the situation with reasoning is similar to motor skills. In addition to a small number of research, there are different results in the studies, in terms of the realized effects of the aquatic program on physical fitness. An important finding is that aquatic programs can have a positive effect on social, emotional, and functional skills. However, more evidence is needed to determine the appropriate dosage of aquatic-based therapy for long-term improvements of social, behavioral and motor abilities.

**Declarations**

**Compliance with Ethical Standards**

**Conflict of interest**

The authors have nothing to declare.

**Author contributions**

ICMJE statement: all authors meet all four ICMJE criteria for authorship and have approved the final version of this manuscript. Dr Salar; Study supervision: had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Dr Jorgic; Acquisition, analysis, or interpretation of data and discussion. Stefan Stojanovic and Pourqoli; Data Extraction and risk of bias assessment. DR Block; revision of the manuscript for important intellectual content.

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**Table**

Table 1 is not available with this version.

**Figures**

**Figure 1**

PRISMA Flow diagram (2020) of inclusion process of the article selections procedure
Figure 2

Risk of Bias assessment