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EFFECT OF AQUATIC THERAPY ON MOTOR SKILL AND EXECUTIVE FUNCTION IN CHILDREN WITH AUTISM SPECTRUM DISORDER

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ABSTRACT

Research has demonstrated the positive effects of different types of physical activity, especially aquatic therapy for children with autism spectrum disorder (ASD). As such, this study aimed to examine the effect of a response-oriented approach using aquatic exercise for children with ASD on motor skills and executive function. In this quasi-experimental design, 40 children aged 7–10 years were randomly assigned to one of two groups: a response-oriented aquatic exercise (ROA) group (n=20) or a control (CON) group (n=20). The Bruininks-Oseretsky Test of Motor Proficiency second edition – Short Form (BOTMP-2) and the Wisconsin Card Sorting Test (WCST) were used to assess motor skill and executive function, respectively. Significant ($p \leq 0.05$) differences were found between the ROA and CON groups in receiving ($F=38.94$, $p=0.001$) and throwing ($F=33.05$, $p=0.001$), static balance ($F=44.89$, $p=0.002$), dynamic balance ($F=48.51$, $p=0.010$), correct responses ($F=3.60$, $p=0.010$), conceptual responses ($F=0.34$, $p=0.010$) and perseverative errors ($F=1.57$, $p=0.040$). Aquatic exercise was found to be an effective intervention for children with ASD in that it decreases motor deficits and improves executive function. This study provides families, teachers and other specialists with exercise optionality that may be exciting and motivational to children with ASD due to its response-oriented approach.

Keywords: Autism, Aquatic therapy, Children, Executive function, Motor skill

INTRODUCTION

Autism spectrum disorder (ASD) is a severe lifelong disability characterised by deficiencies in repetitive behaviour, social and communication skills, and motor deficits (Wilson *et al.*, 2018; Battaglia *et al.*, 2019). Core motor deficits that characterise children with ASD include balance deficits, coordination problems and poor manual dexterity (Bieleninik *et al.*, 2017; Ghayour Najafabadi *et al.*, 2018). Furthermore, although children with ASD display a natural physical appearance, they are often fundamentally impaired in executive function according to the

Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (DSM-IV-TR) (American Psychiatric Association (APA), 2013; Cho *et al.*, 2020). Executive function refers to cognitive control processes such as cognition inhibitory and cognition flexibility. Individuals with ASD do not participate in social learning experiences for acquiring sensory information the same way as others, because of motor deficits (Cho *et al.*, 2020; Bhat, 2021). They may improve cognitive function and motor skills by acquiring homework skills, through observation and by motor learning error (Cho *et al.*, 2020). For this reason, it is inferred that many of these skills are acquired through implicit learning (Ghayour Najafabadi *et al.*, 2018). Because limitations in motor activity may reduce the opportunity to participate in social interactions and learning skills, individuals with ASD will use overt learning to compensate for implicit learning (Bhat, 2021). ASD individuals have decreased activation in their right superior parietal lobule and right precuneus (Brodmann areas 1–9, extending into the intraparietal sulcus) during learning (Licari *et al.*, 2020). Activation in these areas (and in areas such as the right putamen and right supramarginal gyrus) are important for behavioural learning during a task (Ghayour Najafabadi *et al.*, 2018). In addition, individuals with ASD who have severe repetitive behaviour symptoms have been found to have inhibited activation in these regions during motor learning (Licari *et al.*, 2020).

As movement disorders contribute to the main symptoms of ASD (Cho *et al.*, 2020), the goal of physical activity participation is to control the neural mechanisms that support the acquisition and retention of new skills and, in the process, the formation of neurons leads to the regeneration or reorganisation of neural structures in response to physical activity (Licari *et al.*, 2020). Previous research has demonstrated that participation in physical activity participation such as aquatic therapy is attractive and can be effective for children with various disabilities (Shariat *et al.*, 2014; Naumann *et al.*, 2021; Marzouki *et al.*, 2022). In addition to the usual modes of physical exercise, the use of aquatics to rehabilitate children with disabilities is attractive as children are often not eager to pursue traditional physical therapies that may not be meaningful and appealing to them (Goon *et al.*, 2013; Alaniz *et al.* 2017; Dillon *et al.*, 2017; Güeita-Rodríguez *et al.*, 2021; Shaw *et al.*, 2021). Physical activity with response-based principles has rules of learning and the response-based principle is based on a behavioural approach that can affect an individual through social interactions and communication, utilising each child's natural motivation (Naumann *et al.*, 2021). Ketcheson *et al.* (2017) have illustrated the importance of motor programming to improve motor skills among children in early intervention stages (Ketcheson *et al.*, 2017). Recent studies have also shown that various physical interventions can have a positive effect on the social and motor skills of children with ASD, which can improve motor performance and neuromuscular control based on stimulation of sensory stimuli such as muscle tension, pressure and joint tension, and neuromuscular facilitation (Ghayour Najafabadi *et al.*, 2018; Naumann *et al.*, 2021; Marzouki *et al.*, 2022). Therefore, using response-centred aquatic exercises is a motivational approach that allows the child to experience activities and events similar to those in the real world, by providing artificial sensory feedback (Naumann *et al.*, 2021).

Specifically, previous research has shown that aquatic exercises can be designed for children with ASD to include cognitive and behavioural learning approaches (Amoros & Tzvetkovitch, 2014; Battaglia *et al.*, 2019; Güeita-Rodríguez *et al.*, 2021). These aquatic environments are proposed to enrich motor learning by manipulating training conditions that implicitly enhance learning mechanisms based on sensory feedback, motor control, cognition and motivation

(Alaniz *et al.*, 2017). These benefits can be achieved by constructing exercises based on the child's choice, which is enjoyable for the child and helps increase social communication abilities (Battaglia *et al.*, 2019). Research on the social status and communication of children with ASD shows that if these interventions are purposeful and based on a response-oriented approach, they have a better effect on the characteristics of these children than when they are teacher-centred and pre-determined (Pan, 2010). The response-oriented approach is gentle, efficient and enjoyable at the same time because it is based on games. The child has freedom of action to the extent that the child provides the plan to the teacher and plays a role in the work situation. This approach has been found to enhance a child's social and cognitive skills (Ennis, 2011). To our knowledge, research investigating the effect of aquatic therapy with learning through the response-oriented approach has been limited. Therefore, in this study we attempted to utilise a response-oriented approach when using aquatic exercise and investigate its effect on motor skills and executive function in children with ASD.

METHODS

Design and participants

The study made use of a quasi-experimental design. Using a pre- and post-test design we recruited 40 participants with ASD from Iran who were then randomly assigned to a response-oriented aquatic exercise (ROA) group (n=20) or a control (CON) group (n=20). The inclusion criteria were children with a definitive diagnosis of ASD based on the DSM-V criteria; aged between 7 and 10 years from psychology clinics (based on the filled registration forms of four different clinics in four different zones); with the ability to follow instructions and be teachable; with no hearing or vision impairment; classified as high motor functioning based on DSM-V diagnosis; with parental satisfaction with participation (based on the consent form); and with no physical impairments. Children aged 7–10 years old were selected as this represents the period of middle childhood when signs of autism become most noticeable (CDC, 2022). A physician screened potential participants for eligibility to participate in the aquatic training programme (Shariat *et al.*, 2018).

Ethical considerations

The Institutional Review Boards at the University of Tehran approved the study protocol (IR.UT.SPORT.REC.1400.002). As a result, permission to conduct the study was obtained from the relevant institutions and all parents/guardians gave informed consent. As all the children were aged under 18 years, all provided verbal assent prior to participation.

Instruments and procedure

For descriptive purposes, participants were first evaluated for body composition as per the International Society for the Advancement of Kinanthropometry (ISAK) guidelines (Norton & Olds, 1996). Then, body mass was measured and recorded to the nearest 0.1 kg using a digital scale (Jawon, Model IOI-353, Kyungsun City, Korea), and body height was measured to the nearest 0.5 cm using a wall-mounted stadiometer (HM210D, Charder Electronic Co, Ltd., Taichung City, Taiwan).

The Bruininks-Oseretsky Test of Motor Proficiency – Second Edition (BOTMP-2) Short Form was used in this study (Bruininks & Bruininks, 2005). It is a valid measure that uses 8 subscales, including 14 separate parts, to comprehensively measure motor skills. Four subtests measure fine motor competence: 1) fine motor precision (FMP), 2) fine motor integration (FMI), 3) manual dexterity (MD), and 4) bilateral coordination (BC), and four subtests assess gross motor competence: 1) balance, 2) running speed and agility (RSA), 3) upper-limb coordination (ULC), and 4) strength (Ghayour Najafabadi *et al.*, 2018; Bruininks & Bruininks, 2005). The test takes 12–25 minutes to complete. Each raw score on a subtest was converted to a point score to allow performance to be assessed on a graded scale. The individual item points were summed to derive a subtest point score. Total point scores were documented by adding all point scores and using the norm tables to discover percentile rank and standard scores. The range of percentile rank of each child's score for analysis was as follows: 2 or less (well below average), 3–17 (below average), 18–83 (average), 84–97 (above average), and 98 or greater (well above average). The tool's test-retest reliability is 0.89, and the reliability for gross and fine motor skill, respectively, is 0.85 and 0.77 (Shahrasfenghar *et al.*, 2019).

To assess executive function, the computer version of the Wisconsin Card Sorting Test (WCST) was used (Pan *et al.*, 2017). This comprises 4 stimulus cards and 128 response cards. To obtain a good mark, the participants were required to determine the correct sorting principle based on computer feedback and maintain this sorting principle or set. Scores were based on the number of trials managed, the total number of correct responses, the number of errors, the number of perseverative responses, the number of perseverative errors, the number of non-perseverative errors, the number of categories accomplished, the number of trials to complete the first category, conceptual level responses, failure to maintain set, and learning to learn (Pan *et al.*, 2017). The same examiner conducted each assessment pre-and post-test.

Response-oriented aquatic exercise programme

The ROA group participated in an aquatic programme for 8 weeks, three times weekly, for 45 minutes each session at an indoor pool. The study's programme design variables were based on the Halliwick Method of Marzouki *et al.* (2022), with the safety of such aquatic programmes in individuals with ASD being previously described (Grosse, 2014). Four trained coaches with at least 2 years' experience and a psychologist managed each session. Each session commenced with a 10-minute warm-up, proceeded to a 25-minute response-oriented exercise programme and concluded with a 10-minute cool-down. The ROA group participated in the response-oriented exercise programme. The CON group participants were requested not to alter their physical activity patterns for the duration of the study. The control group maintained their daily activities and did not change their physical activities during the intervention. The study procedure is illustrated in Figure 1.

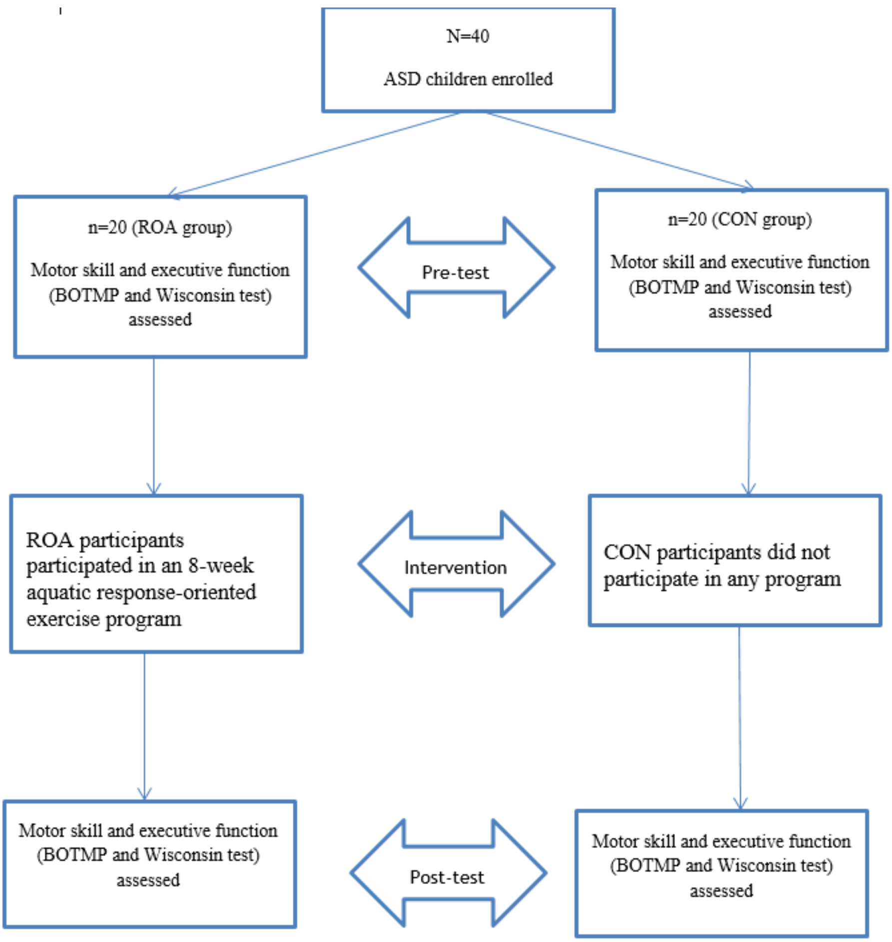

Figure 1. **PROCEDURE OF ENROLLMENT, INTERVENTION AND ASSESSMENTS**

Data analysis

SPSS software version 25 was used in the statistical analyses (IBM Corporation, Armonk, NY, USA). The results were presented as means and standard deviations. The normality of data was assessed using the Shapiro-Wilk test. For intragroup comparison, a dependent t-test was used and a covariance was used for intergroup comparison of analysis test. A probability of $p \leq 0.05$ was set for the study.

RESULTS

All participants completed the training and testing procedures. Table 1 presents for descriptive purposes the characteristics of the participants in both groups relating to age, weight and height. The ROA and CON groups were found to be homogenous at the pre-test for all measured parameters. However, based on pairwise comparisons across time, significant (p>0.05) differences were revealed among subscales related to motor skills such as receiving (p=0.001), throwing (p=0.001), static balance (p=0.002), and dynamic balance (p=0.001) in the ROA group. In addition, conceptual responses (p=0.001) and correct responses (p=0.001) increased significantly, while perseverative errors (p=0.04) decreased significantly from pre- to post-test in the ROA group.

The results showed significant differences between ROA and CON groups in receiving (F=38.94, p=0.001), throwing (F=33.05, p=0.001), static balance (F=44.89, p=0.002), dynamic balance (F=48.51, p=0.01), correct responses (F=3.60, p=0.01), conceptual responses (F=0.34, p=0.001), and perseverative errors (F=1.57, p=0.04) (Table 2). Furthermore, there was a significant difference between ROA and CON groups from pre- to post-test in BC (X^2=6.00, p=0.040). In addition, coordination values of the ROA group in the BOTMP-2 improved from 6.3% at pre-test to 28.3% at the post-test.

Table 1. **DESCRIPTIVE DATA OF CHILDREN WITH AUTISM SPECTRUM DISORDER PARTICIPATING IN RESPONSE-ORIENTED APPROACH AQUATIC THERAPY**

Variables	**Groups**	
	ROA (n=20) (Mean±SD)	**CON (n=20) (Mean±SD)**
Age (years)	7.26±1.54	8.20±1.38
Weight (kg)	32.38±9.21	31.60±8.32
Height (cm)	133.70±12.80	131.60±11.70

ROA = response-oriented aquatic exercise group CON = control group SD = standard deviation.

Table 2. **MOTOR SKILL AND EXECUTIVE FUNCTION CHANGES OF CHILDREN WITH AUTISM SPECTRUM DISORDER PARTICIPATING IN RESPONSE-ORIENTED APPROACH AQUATIC THERAPY**

Variable	Group				F coefficient	*p*-value
	ROA		CON			
	Pre-test	Post-test	Pre-test	Post-test		
Receiving	1.04 (±0.94)	1.90 (±0.85)**	0.60 (±0.59)	0.50 (±0.50)*	38.94	0.001
Throwing	1.35 (±0.81)	2.35 (±1.81)**	0.75 (±0.63)	0.45 (±0.40)*	33.05	0.001
Static balance	1.89 (±1.65)	3.40 (±1.89)**	2.03 (±1.45)	1.10 (±0.8)*	44.89	0.002
Dynamic balance	1.02 (±0.9)	2.80 (±1.80)**	0.88 (±0.60)	0.98 (±0.60)*	48.51	0.01
Correct response	20.30 (±6.91)	29.20 (±7.41)**	19.45 (±6.15)	20.65 (±7.21)*	3.60	0.01
Conceptual responses	0.45 (±0.30)	2.00 (±1.26)**	1.40 (±0.50)	1.90 (±0.85)*	0.34	0.001
Perseverative errors	21.21 (±7.86)	14.29 (±7.71)**	21.12 (±7.43)	20.21 (±6.50)*	1.57	0.04

ROA = response-oriented aquatic exercise group CON = control group.

*Significant (p≤0.05) difference between ROA and CON groups; **significant (p≤0.05) difference between pre- and post-test.

DISCUSSION

Previous studies on the effects of motor learning in children with ASD have shown that exercise programmes are useful for increasing motor and cognition skills (Bremer *et al*., 2016; Ghayour Najafabadi, 2018). However, regarding aquatic exercise programmes, one study has shown an improvement in motor skills and executive functions (Marzouki *et al*., 2022), whereas only a few empirical studies have recommended the usefulness of this strategy in the treatment of motor and cognitive impairments in children with ASD (Tse *et al*., 2019; Monteiro *et al*., 2022). As such, the current study aimed to determine the effect of a response-oriented approach using aquatic exercise for children with ASD on motor skills and executive function.

The results of this study demonstrated improvements in gross motor skills and executive function following 8 weeks of ROA exercise. These improvements are supported by previous research demonstrating the beneficial effect of aquatic therapy on various aspects of gross motor skills and executive function in individuals with ASD (Gardiner & Iarocci, 2018, Ansari *et al*., 2021; Marzouki *et al*., 2022). Specifically, regarding gross motor skills such as object control (galloping, hopping and leaping) and locomotor skill (catching, throwing and dribbling), Marzouki *et al.* (2022) reported that 10 weeks of an aquatic programme was effective in improving locomotor ability in three groups of children with ASD aged 7–10 years, focusing on technical aquatic therapy compared with game-based aquatic therapy programme designs. Similar improvements were found in a study by Ansari *et al.* (2021), who found improvements in static and dynamic balance following a 10-week aquatic programme with 30 children with ASD aged 8–14 years. Interestingly, improving balance as a motor skill could affect communication and social interactions (Ansari *et al.*, 2021). Therefore, regarding motor skills, the findings support previous suppositions that aquatic therapy can result in complex adaptations of the neuromuscular system and improve the transmission of neural impulses (Fournier *et al.*, 2010). Furthermore, because water density is 800 times greater than air density, aquatic therapy may enhance muscle strength through a resistive medium without extreme pressures on the weight-bearing joints (Naumann *et al.*, 2021).

In addition to physical improvements, previous studies have stated that exercise could be operational and stimulate processes improving executive functions (Gardiner *et al.*, 2018, Demetriou *et al.*, 2019). Whereas the findings of this study are novel in children, the previous study by Tse *et al.* (2019) demonstrated that 12 weeks of physical activity can improve executive function (inhibition control and working memory) and quality of sleep of 8–12-year old children with ASD. Another study by Pan and colleagues (2017) conducted with a sample of 22 children with ASD revealed that a physical intervention can improve executive function (cognitive flexibility) and motor skill proficiency in 12 weeks (Pan *et al.*, 2017). These improvements in executive function in children with ASD could be as a result of the children with ASD improving their activation of the neuron tract and messaging transfer from the brain to the body in order to perform movement (Courchesne *et al.*, 1988). A further possible supposition for the cognitive advantage is related to the neurotrophic hypothesis (Khan & Hillman, 2014). According to this hypothesis, exercise, irrespective of type, increases metabolic demands and triggers a cascade of biochemical changes, such as increasing cerebral blood flow and enhancing the accessibility of brain-derived neurotrophic factor (Khan & Hillman, 2014). This, in turn, enhances brain plasticity for developed-level cognitive activities such as those elaborated in executive functions (Gomez-Pinilla & Hillman, 2013). Another explanation for the success of this intervention could also be related to the elements of the dynamic systems theory, which advocates that movement patterns develop as a result of a complex interaction between the environment, task and learner. The varied experiences of the child with ASD in relation to the task and environment can result in motor skill acquisition and movement patterns (Lee & Porretta, 2013). In addition, based on self-regulation theory, an ROA exercise programme may modify an individual's own affective or behavioural responses according to environmental demands and increase motivation to participate in other programmes.

There are several limitations to this study, one of them is that the current study findings cannot be generalised to other specific age groups of children or even adults. In addition, this study did not make comparisons between various design considerations (i.e., type of aquatic therapy, volume, duration, frequency, etc.) that could have influenced outcome measures. Finally, different motivational factors and physical activity levels may have been present in the participants, which this study did not measure. Future studies should determine if aquatic therapy has any positive effects on motor skill and executive function in children of differing age groups along the entire spectrum of ASD, to determine the global and specific effects of aquatic therapy.

CONCLUSIONS

In conclusion, this study demonstrated significant improvements in gross motor skills and executive function following 8 weeks of ROA exercise. These findings provide additional evidence for using aquatic activities to simultaneously improve the interrelated domains of motor skills and executive function in children with ASD. Furthermore, the results suggest that aquatic exercise may provide an alternative or complementary exercise modality to families, teachers and specialists that could be implemented in the educational and vocational treatment of children with ASD to promote not only their physical but also their executive function.

Conflict of interest

No conflict of interest is reported.

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