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Effects of early swimming in infants with autism spectrum disorders

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ABSTRACT

The number of individuals with autism spectrum disorder (ASD) affecting the development of their perceptual-motor skills and social functioning has been rapidly increasing in recent decades. It is essential to find a novel and effective way for them to develop their skills. Computer systems could improve diagnostic assessment, provide significant support for research, and enhance communication, as well as the assessment of the impact of early swimming on health, motor, social, and cognitive development. Research on early swimming exposure using animal models can provide insights into potential effects on various developmental aspects. Laboratories create genetically modified mice or fish carrying gene variations associated with ASD. To study the behavior of mice or fish, researchers often use video recording, including infrared cameras that enable activity recording without disrupting animal behavior. Video recordings are analyzed using software that can identify and track specific behavioral patterns, movement, or other parameters of interest. This allows researchers to quantify and analyze data in a way that would be challenging or impossible with other methods. The aim of this study was to analyze existing research results that examined early swimming in newborns and infants with ASD, as well as animal models (mice, fish, etc.), to illustrate how water exposure affects their health and development. Additionally, the study aimed to enhance early swimming programs for individuals with ASD through computerized systems.

Keywords: early swimming, autism spectrum disorders, technology

INTRODUCTION

Water activities for young children attracted the attention of researchers as early as the second half of the 20th century (Fouace, 1970). It has been discovered that early swimming, or “baby swimming,” can positively impact the development of individuals with autism spectrum disorder (ASD). ASD is a complex neurodevelopmental disorder characterized by atypical social behavior, repetitive sensory-motor behavior, and difficulties in verbal and non-verbal communication (Hirota & King, 2023). Symptoms can be observed before the age of three, and diagnosis is possible around 18 months of age (Brentani et al., 2013). In addition to these characteristics, other emotional states such as depression, anxiety, and fear have been noted (Asdaq et al., 2024; Güeita-Rodríguez, 2021; Stevanović, 2021). The causes are considered to include genetic events, metabolic disorders, infectious diseases, and structural abnormalities in the brain (Roy et al., 2015). In addition to being a popular physical activity, it has been found that individuals with ASD greatly enjoy the water environment and the increased freedom of movement (Lee & Poretta, 2013; Pan, 2010; Yilmaz et al., 2004). The buoyant force, turbulence, and resistance create unique conditions for easier learning and the development of motor skills (Lee & Poretta, 2013). Various water-based programs, from simply being in the water to targeted training, have shown positive effects on gross and fine motor skills, visual perception of movement, and cognitive flexibility in children with and without ASD (Alaniz et al., 2017; Brito Mancheno, 2024; Caputo et al., 2018; Ennis, 2011; Fragala-Pinkham et al., 2010; Hariri et al., 2022; Pan, 2010, 2011; Santos et al., 2023; Yilmaz et al., 2010). Aquatic programs for children with ASD have shown improvements in swimming skills, physical fitness, social interaction and behavior, water safety, and a reduction in stereotypical self-stimulatory behavior (Fragala-Pinkham et al., 2011; Güeita-Rodríguez, 2021; Lawson et al., 2020; Prupas et al., 2006; Yilmaz et al., 2004). In addition to positive changes in motor skills, positive changes in the behavior of children with ASD have been observed (Johnson et al., 2021) as well as in communication skills (Azimigarosi et al., 2020). The impact of swimming for babies, aged 3-36 months, is significant because there is no break in water exercise between baby swimmers and the age when swimming techniques are taught (Kocić et al., 2023). Swimming from an early age contributes to physical health, improved cognitive functioning in children, provides multisensory stimulation to the somatosensory system (Piljak & Kocić, 2022), and offers benefits for premature and newborn babies (Santos et al., 2023). Early swimming intervention is a non-invasive method that has been proven to enhance brain development in young children and treat neurodevelopmental disorders (Meng et al., 2022). The

Table 1. Inclusion and exclusion criteria for papers

Inclusion criteria	Exclusion criteria
Swimming for babies and water exposure for newborns and infants with ASD	Abstracts without displayed full papers
Studies involving components influenced by swimming	Sample of participants not falling within newborns and infants up to 36 months or an animal model not corresponding to the age
Participants under 3 years of age with a primary diagnosis of ASD	Research including children over 36 months of aga as study participants who are not from the ASD
Newborns and infants of both genders up to 36 months of age	Research including children disabilities, premature infants, or sick children as study participants who are not from the ASD
Water activities and swimming programs for babies and for the animal model of ASD	
Studies involving computer system to enhance diagnostic assessment and provide significant support for research and the assessment of the impact of early swimming	
Research encompassed until October 2023	

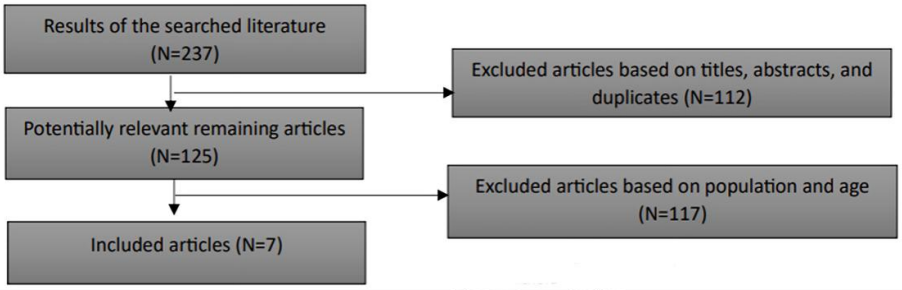

Figure 1. The process of searching and selecting articles (Source: Author's own elaboration)

development of technology has spurred new research, monitoring, and early swimming training (Guo, 2021) and in recent decades has provided much useful information in studies related to ASD (Vyas, 2021). The ability to mimic biological design enables computers to perform various tasks (Kumar et al., 2021), including measuring the position of children with ASD while they swim (Pan et al., 2023). The aim of this study was to analyze existing research results that examined swimming in newborns and infants with ASD, illustrating how early swimming and water exposure affect their health, motor, social, and cognitive development through computer-assisted technology.

METHOD

The inclusion criteria were studies conducted on infants with ASD and animal models, assessing the impact of swimming on their health, motor, social, and cognitive development, as well as water behavior patterns (water familiarization, overcoming fear of water, floating, swimming with song and rhythm, learning breathing techniques, and spatial awareness). **Table 1** displays the corresponding criteria based on which specific studies were included in this review and excluded from it.

Search Strategy

A systematic literature search was carried out using the following electronic databases: Web of Science, PubMed, Google Scholar, KoBSON, and SCIndeks. The final search was completed in October 2023. The search strategy employed systematic terms such as ASD, autism, baby swimming, development, motor development, water exposure, early swimming, sport, health, infant swimming, swimming benefits, motor ability, and others. Titles and abstracts of all articles that satisfied the inclusion criteria were evaluated, with full-text articles then selected for detailed analysis.

The search identified 237 potentially relevant articles related to swimming and water exposure (including activities such as water familiarization, overcoming fear of water, floating, swimming with song and rhythm, learning breathing techniques, and developing spatial awareness) for newborns, infants, and infants with ASD. After screening titles, abstracts, and removing duplicates, 112 studies were excluded. Of the remaining 125 articles, 117 were excluded based on criteria such as age, premature birth, participants not on the autism spectrum, or individuals with other types of disabilities. This screening process resulted in 8 studies that were selected and analyzed in this review. A detailed overview of the literature search and selection process is presented in **Figure 1**.

RESULTS

The results of the studies included in this research are presented in **Table 2**. Among all the studies, three were conducted on rats aged 8 days, equivalent to children aged 1 to 2 years. Three studies were conducted on the animal model of autism in zebrafish. One of the included studies was conducted on children diagnosed with ASD. The treatments administered to the

Table 2. Characteristics of the included studies

Author(s)	Participants	Activity	Instruments	Results
An et al. (2023)	Rats	Swimming with resistance	Computer monitoring	Poor muscle strength in mice with modified Shank3 gene, improvement in strength after intervention, and exercise positively influences the treatment of neuro-pathology in ASD with gut microbiota
Dan et al. (2023)	Rats	Swimming	Computer monitoring	Swimming enhances social behavior, learning, and memory capacity
Kozol et al. (2015)	Zebrafish	Water immersion and swimming	Camera & software	Reducing Singap1 or Shank3 genes or both genes results in slower development, unproductive movement, and cell death
Liu et al. (2018)	Zebrafish	Swimming	Computer monitoring, video track software, & camera	Mutation arising as a result of CRISPR/Cas9 gene editing, established morphological, behavioral, and neurological characteristics in early and adult age
Liu et al. (2021)	Zebrafish	Water immersion and swimming	Video cameras & computer monitoring	The lack of the Shrank3 gene causes social deficits and stereotypical behaviors and water physical activity has positive effects on stereotypical behaviors
Meng et al. (2022)	Rats	Swimming	Infrared cameras & computer monitoring	Improvement of social interaction, social memory, and reduction of stereotypical behaviors
Rogers et al. (2010)	Boys with ASD	Water immersion and swimming	Multicolored hair bands	Increase in motivation, development of positive emotions, rise in desire for activities, and positive changes in speech

participants in these studies included activities ranging from water immersion to resistance swimming. The results indicate a connection between early swimming and motor, social, and cognitive development. It has been found that swimming has a positive effect on neurodegenerative diseases that can occur due to the deficiency or mutation of the Shank3 gene. In addition to increasing muscle strength and endurance, improving social interaction, social memory, and reducing repetitive behaviors, swimming plays a significant role in the prevention and recovery of neurodevelopmental disorders.

DISCUSSION

ASD is a neurodevelopmental disorder characterized by deficits in verbal and nonverbal communication, social impairments, and stereotypical behaviors (Kozol et al., 2015). In addition to these characteristics, ASD may involve motor impairments, reduced intellectual abilities, sensory disorders, obsessive-compulsive disorders, and attention deficits (Hewitson, 2013). It manifests before the age of three during the early stages of brain development. The prevalence of this phenomenon has been increasing annually. Intentional deletion or mutation of the Shank3 gene in laboratory conditions leads to developmental disorders characteristic of ASD (An et al., 2023). The deficiency of this gene is considered the most common risk factor for the onset of ASD. Swimming represents both a fun physical activity and an essential life skill that every child should master at an early age (Anušić, 2020). Early water activities have a positive effect on children's motor development (Piljak & Kocić, 2022) and ensure better adaptation to new situations (Diem, 1982). Water activities require adaptability and are considered the most effective exercise program for neurodevelopment, especially in infants and children (Cheng et al., 2018). Programs for babies involving water exposure and/or swimming improve early motor development in infants (Borioni et al., 2022; Dias et al., 2013; Leo et al., 2022; Pereira et al., 2011; Piljak & Kocić, 2022; Sigmundsson & Hopkins, 2009), have a positive impact on neuro-psychomotor development (Araujo et al., 2023; García et al., 2016), and enhance visual perception of movement (Blystad & van der Meer, 2022). Therefore, water activities from an early age stimulate and enhance the development of infants across various aspects. Swimming plays a significant role in maintaining mental and physical health, as it is crucial for the nervous system, skeletal muscles, and cardiorespiratory function (Aguiar et al., 2011). Additionally, it helps alleviate symptoms in ASD (Ennis, 2011; Pan, 2010; Yanardag et al., 2013; Yilmaz et al., 2004) and has a positive effect on treating ASD (An et al., 2023). Mechanisms through which swimming improves neurological disorders include the expression of neurotrophic factors (Boracı et al., 2020; Dan et al., 2023; Meng et al., 2022; Sigwalt et al., 2011), changes in synaptic structural proteins (Dan et al., 2023; Liu et al., 2018; Meng et al., 2022), alterations in synaptic receptor expression (Boracı et al., 2020; Dan et al., 2023; Ko et al., 2013; Meng et al., 2022), and modifications in neurotransmitter release (Dan et al., 2023; Leite et al., 2012; Meng et al., 2022). Many studies conducted on animal models (Fontana et al., 2022; Kalueff et al., 2013; Meshalkina et al., 2018; Ogi et al., 2021; Oliveira, 2013) show that the loss or mutation within the Shank3 gene can induce stereotypical behavior and social impairments, which are considered characteristic of ASD (Dan et al., 2023; Liu et al., 2021; Mei et al., 2016; Meng et al., 2022; Peca et al., 2011; Zhu et al., 2018). This deficiency in the Shank3 gene results in structural changes in brain proteins (Dan et al., 2023; Meng et al., 2022; Peca et al., 2011; Wang et al., 2017; Yoo et al., 2018) responsible for social behavior, communication, and cognition (Liu et al., 2021). The age of the animal models corresponds to the age of 1-2 years in humans, which is the earliest period for ASD diagnosis (Dan et al., 2023; Meng et al., 2022). In animal models lacking the Shank3 gene and exposed to swimming treatment, positive changes within brain synapses have been observed. This suggests that swimming, as a multisensory and motor stimulation, can greatly improve the development of synaptic abnormalities characteristic of ASD. The early postnatal period is crucial for the prevention and treatment of diseases caused by Shank3 gene mutations (Dan et al., 2023; Liu et al., 2021; Meng et al., 2022). Studies conducted on individuals with ASD focus on motor and social skills. The results of these studies indicate improvements in physical fitness and endurance in children with autism (Fragala-Pinkham et al., 2008; Pan, 2011; Yanardag et al., 2013), as well as the development of social interaction, emotions, and learning (Chu & Pan, 2012; Ennis, 2011; Pan, 2011). In contrast to the development of these skills, a reduction in stereotypical behavior has been observed in children with ASD (Yilmaz et al., 2004).

CONCLUSION

ASD is a neurodevelopmental disorder characterized by social impairment and stereotyped behavior, and its incidence rate is increasing year by year. Analyzed studies confirm the potential of early swimming therapy for ASD. Early swimming programs for infants, including activities for infants aged 3-36 months, have a positive impact on the development of motor, social, and cognitive abilities. Water provides unique sensory stimulations that can assist children with autism in processing and integrating sensory information, contributing to improving their ability to cope with their environment. Movement in water stimulates the function of different muscle groups, strengthens muscles, and improves coordination of movement, while group swimming provides an opportunity for the development of social skills, contributing to improved communication and social integration. Analyzing early swimming intervention studies on animal models (mice and zebrafish) of ASD has yielded similar results in behavior to previous authors. These models can provide important insights into the functioning of genes responsible for the onset of ASD and potential implications for people with ASD. The Shank family (SHANK1, SHANK2, and SHANK3) has become a powerful gene for modeling ASD in animals. This research approach on animal models indicates the connection between genetics, gut microbes, behavior, and the impact of exercise (in this case, swimming) on processes related to ASD. It is essential to note that, although this research can provide useful information about the potential effects of early exposure to swimming, the direct transfer of results to humans must be approached with caution. Nevertheless, this research can contribute to understanding the complex connections between genes, physiology, and behavior in the context of neurological disorders such as ASD. It can also provide a foundation for further study and a better understanding of the potential benefits or challenges of early exposure to swimming in different biological contexts. Early swimming intervention reduces stereotyped behavior and improves social deficits, making it one of the most effective exercise programs for neurodevelopment and neuroplasticity. Challenges in assessing children with ASD in the early ages of 3 to 36 months and the lack of available literature on early “baby swimming” pose certain limitations in research. The scarcity of available literature on the impact of swimming for babies and difficulties in collecting enough infant participants are likely causes for sometimes arbitrary age selection in the literature, leading to a series of inconsistent results. There is limited information on this topic, but the results show that early swimming for babies is extremely beneficial for overall development. Studies examining the use of computers, technology, and visual aids to supplement and improve swimming instruction for participants with ASD are valuable in diagnosing ASD, therapy, and research in general. It is worth noting that further research, both on animal models and participants, will be needed to understand the specific mechanism by which swimming improves ASD.

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