



REVIEW

Effect of Physical Activity Interventions in Autism Spectrum Disorder

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Abstract

Autism spectrum disorder (ASD) is a pervasive developmental disorder with limited social and communication skills, and limited and repetitive movements. Motor skills in these individuals may differ compared to their peers. It is known that it creates a special risk group because it increases the risk of heart diseases, diabetes and obesity. It is thought that physical activity will also be effective on individuals with autism in terms of proving that it is an effective tool in reducing these risks in individuals with normal development. Despite the partial success of standard treatment methods for ASD, there has been an increase in recent years that physical activity can have positive effects on children with autism. According to the studies examined, it is stated that physical activity reduces the maladaptive behavior patterns of people with ASD as well as physical development. In the studies reviewed in the literature, it has been determined that participation in physical activity in children with autism reduces stereotypic behaviors. In addition, it has been found that physical activity has positive effects on communication skills, sensory skills and academic skills of children with communication autism. In this review, the effects of physical activity interventions on individuals with ASD are discussed.

Keywords

Autism Spectrum Disorder, Exercise, Motor Skill, Physical Activity

INTRODUCTION

Children with autism spectrum disorder (ASD) have social and behavioral difficulties, which make peer communication and interaction challenging and lower their levels of physical activity. (Siracusano et al., 2021). On the other hand, physical activity provides a crucial setting for enhancing one's health and social interactions. The development of personal health and social skills may therefore be aided by teaching children and adolescents with ASD good and consistent exercise habits. In these children, it may be beneficial to move the adaptation process to physical activity more slowly. In addition, motivation for the activity can be increased by using pictures and similar interests (Iliadis & Apteslis, 2020).

Due to the fact that there is no psychopharmacological treatment that has yet been

proven effective to prevent or treat ASD, it is also important to investigate non-drug methods of controlling symptoms. The aim of this study is to review the effects of different physical activity initiatives in children diagnosed with ASD by scanning the related literature. January May 2021, PubMed, Scopus and Web of Science databases were searched for this purpose, and the studies that are available in the databases and examine the effects of physical activity in individuals diagnosed with ASD were reviewed. Review the order, the definition and epidemiology of ASD, autism symptoms, autism treatment practices for the physical and mental health and physical activity in individuals with autism with have been mentioned regarding the effects on physical activity and ASD.

Definition and Epidemiology

Autism is an organic damage that causes perceptual impairment and means "Autos" in

Greek. Autism, which usually occurs in the first two years of life, is a developmental disorder that inhibits social and communication skills (Kundu et al., 2022). ASD; It is a neurodevelopmental disorder characterized by deviations in social and emotional interaction and communication, restricted and repetitive behaviors, and abnormalities in senses such as hearing, sight, taste, and touch (Klein et al., 2022).

Autism symptoms and their level in these children who have learning and perception difficulties may differ in each child (Leekam et al., 2007). In the DSM-5 (Diagnostic and Statistical Manual of Mental Disorders-5) published by the American Psychiatric Association (APA) in 2013, autism severity levels were examined in 3 ways. These are as follows:

Level 1: Inflexibility in behavior causes significant impairment of functionality in one or more contexts. Has difficulty switching between activities. Editing and design issues prevent it from being independent. Support training is needed.

Level 2: Behavioral inflexibility, difficulty with change, or other restricted/repetitive behaviors occur frequently enough to be seen by an ordinary observer and impair functioning in various contexts. Has great distress/difficulty in changing his focus and action. Intensive supportive training is required.

Level 3: Inflexibility in behavior, excessive difficulty in the face of change, or other restricted/repetitive behaviors significantly impair functionality in all areas. Has great distress/difficulty in changing his focus and action. Significant support training is needed (Diagnostic and statistical manual of mental disorders: DSM-5™, 5th ed, 2013).

Autism is an important neurobiological disorder that is most frequently encountered in clinics, especially after diseases such as cancer, down syndrome and childhood diabetes, which are seen at a high rate in early ages. About 1 in 100 children worldwide are diagnosed with autism spectrum disorder. The most recent estimates of the prevalence of ASD in the United States are 23.0 per 1000 (one in 44) 8-year-old children, and ASD is 4.2 times more common among boys than girls (Maenner et al., 2021).

Due to the interaction and communication disorders of individuals diagnosed with ASD, some problems arise in their behavior patterns (Siracusano et al., 2021). Children with autism

typically lag behind their peers in the development of motor functions. Although it is stated by the American Psychiatric Association that individuals with Asperger's syndrome often have impaired motor function, these motor incoordination are commonly seen in all levels of autism.

In a study, it was shown that 41% of children with autism demonstrated clinically lower motor performance (Dewey et al., 2007). It has been stated that some children with Autism reach walking level longer than their peers and may be clumsy in gross motor movements (Gong et al., 2020). In this study, the importance of the participation of autistic children in physical activity on motor competence and problem behaviors in individuals was tried to be emphasized.

Clinical Symptoms of Autism

Especially 12-18 months are critical for early diagnosis in ASD. Recognition of symptoms can be noticed by nurses and doctors during the examination, with information from parents (Crais et al., 2014). Among these symptoms; different obsessions, lack of social communication and interaction in behaviors, stereotyped, limited and repetitive situations; Language used in social interaction and at least one of the deficiencies in symbolic play skills include delays or unusual functionality before the age of 3 (Hyman et al., 2020).

While the rate of manifestation of symptoms becomes more pronounced in 70% of children, it is seen in 30% of children with developmental delay at 18-24 months. According to the Autism and Developmental Disabilities Monitoring Network, the mean age at diagnosis was 50 months (Maenner et al., 2021). Mostly, ASD can be recognized at the end of 2-3 years after the symptoms start to be noticed. The definitive diagnosis cannot be determined by laboratory tests. Children have a very important place in diagnosis by observation method (Lord, 2012). The Autism Diagnostic Observation Schedule, Second Edition (ADOS-2) is widely used to aid in the clinical diagnosis of ASD and is currently considered the gold standard assessment tool for ASD. ADOS consists of 4 modules; Which module the case will take is determined by the level of language skill. ADOS-2 also has a baby module. ADOS ensures that the case is evaluated in a social environment as close to reality as possible. After the examination, which takes about 45-60 minutes,

there is an evaluation part of 15-20 minutes. The natural observation environment created between the examiner and the subject during ADOS, when combined with standard games, activities and social situations, allows for the standard evaluation of ASD symptoms. This is an extraordinarily important feature for ASD, whose symptoms are very complex. ADOS Modules 3 and 4 can be applied to adolescents and adults. This is very important in terms of standard evaluation in older individuals, especially in atypical cases (Kalb et al., 2022).

Social communication inadequacies of children are one of the important symptom features of ASD. Due to the inadequacy in social interaction, their imitation abilities are also limited (Kilroy et al., 2022). Diagnosed children have significant cognitive impairments, it is observed that their intelligence level is lower than 70, and they exhibit severe stereotypical movements and destructive behaviors. It is also stated that eating and sleeping problems can be encountered (Guller & Yaylaci, 2022). Although stereotypic situations in behavior are usually evident at the age of 4, they can be observed in some of the children in their second year (Alsayouf et al., 2021).

It is seen in literature reviews that children with autism are prone to gain weight. The prevalence of obesity in children with ASD was found to be 17%. The relative risk of obesity in these children compared to control children was estimated at 1.58 (Sammels et al., 2022). It is stated that the emotional states of children with ASD are more negative than their peers (Martínez-González et al., 2021). The first reports of ASD are generally made by the evaluations of parents and health professionals (Bhat et al., 2014). Unable to respond to voices and smiles, not making much eye contact, and not liking to be cuddled are observed. In language development, it has been observed that children with ASD have not yet developed in situations such as not being able to express meaningful words expected around the age of one, or being able to form a two-word sentence expected from a child who has reached the age of two, having a vocabulary appropriate for their age, and understanding the commands given (Peiris et al., 2022). Children's motor and non-verbal cognitive developmental retardation is accompanied by inadequate social and communication development. Reflecting and sharing emotions (smiling, looking at other people)

are limited in facial expressions. The ability to play symbolic games, to make and execute games with each other is limited. Verbal and motor imitation skills are insufficient (Doğan & Çolak, 2022).

The most common behavior problems seen are; While behaviors such as crying, hurtful angry behaviors, tantrums, hair pulling, repetitive movements, clapping hands, running on fingertips, shouting are observed, certain movements in inappropriate situations are observed. At the end of the developmental period of children with normal development, loss of communication and social skills can be observed. Loss of communication and social skills is in 20-35% and usually 13-18. observed in months (Tager-Flusberg et al., 2009). Various psychiatric disorders such as bipolar disorder, hyperactivity, attention deficit, and depression are observed (Hsu et al., 2022).

Autism Treatment Process

Individuals with ASD and their parents require a tailored treatment plan. Intervention may differ depending on age, condition of the child, additional physical and mental disorders, and the treatment to be applied requires a multidisciplinary approach (Frye, 2022). Hormone and gene therapies have gained popularity in the fight against autism in recent years (Benger et al., 2018; Yamasue & Domes, 2018). Despite this, the most commonly used treatment method for autism today is a continuous and intensive special education and rehabilitation program (Migliore et al., 2012).

Treatment targets for autism in the National Institute for Health and Care Excellence (NICE) guidelines; To enable autistic individuals to reach their potential, to treat concurrent physical and psychological diseases that impair the adaptation and functionality of parents or individuals, to support caregivers, to provide education, environmental support and certain evidence-based treatment methods to individuals with ASD (Crowe & Salt, 2015).

Definitive treatment in autism is not possible today, but the most effective and promising approaches in reducing basic problems are educational, habit-forming approaches and rehabilitation programs that are started at an early age with the required time and intensity. Social and physical activities among individuals with special needs, especially for autistic individuals, have an important place in the formation of a more effective, healthy communication and social

development in the treatment and rehabilitation phase of these children (Memari et al., 2015).

ASD and Physical Activity

Physical activity (FA) has a wide range of definitions in the literature. Every movement that requires the use of skeletal muscles and the energy we need while these muscles are working is defined as a physical activity (Thompson et al., 2012). Baltacı et al., on the other hand, defined PA as activities that occur with energy expenditure by using muscles and joints in daily life, increase heart and respiratory rate and result in fatigue at different intensities (Baltacı et al., 2008).

Regular physical activity increases muscle strength and endurance, as well as increases capillary density (Rosenblat et al., 2022). Physical activity; It supports the individual to maintain proper posture, strengthens physical performance by increasing bone density and connective tissue density. In addition, it decreases the reflex-reaction time by increasing muscle flexibility and sensorimotor sensitivity and reflex-reaction ability, thus improving balance control skills (Filar-Mierzwa et al., 2021). Physical activity improves general health status and body composition, and improves cardiovascular, respiratory and Supports metabolic functions. It increases the volume of blood pumped to the body by regulating blood pressure (Lavie et al., 2015). It reduces the risk of early dementia and forgetfulness due to increased blood flow to the brain. It helps weight control by accelerating metabolism (Bek, 2008). Contributing to weight control in childhood and adolescence prevents the obesity problem that may be encountered in adulthood (Chin et al., 2016). Physical activity increases coordination between muscles and develops fine and gross motor skills (Hassani et al., 2022).

PA and exercise are necessary and important in healthy children as well as in children with chronic diseases (Smith et al., 2022). Healthy children should follow the daily 60-minute moderate-to-severe FA recommendations in line with the recommended guidelines. However, establishing the appropriate exercise prescription for children with chronic diseases involves more specialized studies and requires careful assessment of the risks and benefits. Clinicians have difficulties in determining the dose of PA or appropriate PA modes to prescribe to their patients. Similar to pharmacotherapy, the parameters of PA such as frequency, type,

intensity and time vary depending on the existing chronic disease and the child's health and physical fitness levels (Shields et al., 2012).

In this period when even children with normal development prefer a more stable and sedentary life, it is an important issue for individuals with autism, who has an important place among individuals with special needs, to participate in and maintain physical activity. In addition to the deficiencies of children with autism in social areas, stereotyped interests and a more sedentary life combine, various negative consequences and disorders can occur in these individuals (Jones et al., 2017).

Children with ASD, who do not have enough strength to reach physical activity opportunities and rights equally or are disadvantaged in terms of resources, actually improve their gross and fine motor functions, healthy developments in the musculoskeletal system, as well as reductions in stereotypical repetitive behaviors and movements, with the exercise programs they participate in. Although they show positive improvement in many aspects such as social communication, it is known that these activities are neglected today (Menear & Neumeier, 2015).

Studies have reported that there are positive developments in the academic achievement and psychosocial aspects of children participating in physical activities. Participation in physical activity and exercise programs is of great importance in individuals with special needs as well as in individuals with normal neuromotor development. It is stated that with participation in physical activity programs and regular exercise programs in trainable mentally disabled individuals, their self-confidence increases again and they establish more effective and healthy social relations with their peers (Aydemir et al., 2020).

Obesity itself is the primary risk factor for heart disease for all ages. It is argued that controlled and gradual weight loss achieved with physical exercise programs gained at an early age in autism will be effective in reducing the risk associated with diabetes, hypertension, hyperlipidemia and cardiovascular disease-related complications (Flygare Wallén et al., 2018). Although success has been achieved with standard ordinary treatments in clinics and rehabilitation centers for the neuromotor development of individuals with autism and many different

treatment methods have been introduced, the idea that exercise and physical activity programs applied to individuals with autism have positive effects on the psychosocial and neuromotor functions of individuals with autism has become widespread day by day (Zoccante et al., 2021). It has been stated that exercise in individuals with autism not only has a positive effect on the musculoskeletal system in these children, but also significantly corrects abnormal stereotyped behavior disorders in these children (Ferreira et al., 2019). It has been reported that participation in physical activity at an early age in children with autism largely corrects the abnormal stereotyped behavior disorders encountered in these individuals. It has also been stated that there is a positive relationship between physical activity and exercises in the social communication skills of autistic children and their success in school (Hilton et al., 2020).

Participation in physical activity reduces stereotyped movements, especially in children with autism (Ferreira et al., 2019). Regular participation in physical activity reduces depression in children with autism, as in all individuals with special needs, and improves their quality of life by improving their psychology. In a program that showed strength and endurance training, nutrition education and stress reduction techniques to create a healthy lifestyle in young individuals with ASD, it was shown that participation in 90-minute classes twice a week for six weeks increased the motivation to participate in exercise and improved mood (Spratt et al., 2018).

When autistic individuals participate in physical activity programs as a group with their peers, there is a great improvement in social characteristics in this autism (Zhao & Chen, 2018). It is stated that exercise and sports activities are generally more beneficial than other fields in socializing and experiencing a sense of academic achievement in individuals with autism. Participation in individual or group-based physical activities is recommended, especially in children with autism, in order to ensure their physical and mental development and to establish good relations in the society (Howells et al., 2019). At this point, the main question is how physical activity should be performed. A meta-analysis comparing individual and group-based exercise programs showed that individual programs had a greater impact on social skills than group programs

(Sowa & Meulenbroek, 2012). The disadvantage of individual programs is that they may not be motivational or practical. Another point that should be noted is that special classes consisting of only children with ASD have been shown to be more beneficial for social functionality, improvements in muscle strength and endurance, and motor skill development compared to mixed classes (Healy et al., 2018).

Participation in physical activity and sports activities allows individuals with autism to be in interaction with different people and different places by removing them from the family environment they are used to. Increasing physical activities with sports activities and exercises is a tool that enables individuals with autism spectrum disorder to get away from the family and home life they are used to, in a different environment, to establish new interactions and social relationships with their peers with whom they did not know and communicate before (Iliadis & Apteslis, 2020).

Although ASD is not one of the primary diagnostic categories, it is known that 79% to 83% of children with ASD struggle with age-appropriate motor abilities (Green et al., 2009; Hilton et al., 2011). Throughout development and youth, these motor limitations are seen. Children with ASD have also been found to have delays in their fine and gross motor skills, though it is unclear if these delays can be distinguished from more general developmental delays in these kids. (Landa & Garrett-Mayer, 2006; Provost et al., 2007). Regardless of whether there is an intellectual handicap, children with ASD frequently have limitations in their motor activity (Bhat et al., 2011). 97 percent of children with ASD and intellectual disabilities and 70 percent of those with ASD and normal or near-normal intelligence were found to be unable to perform age-appropriate motor skills on a standardized motor test, according to Green et al.'s cohort study of 101 school-age children with ASD (Green et al., 2009).

Participation in activities that promote the development of age-appropriate social, communicative, behavioral, and cognitive skills may be hampered by difficulty performing age-appropriate motor skills (Bhat et al., 2011). As well as this, motor impairments can reduce participation in physical activity, which is essential to support optimal health and fitness (Srinivasan et al., 2014). Individuals with ASD exhibit low levels

of physical activity. These individuals are more likely to be overweight or obese than their non-ill peers (McCoy et al., 2016).

Due to some motor impairments or variations in other areas that affect how they learn motor abilities, children with ASD may have trouble completing age-appropriate motor skills (Moraes ve et al., 2017). Children with ASD exhibit deficits in postural control, motor planning, and motor imitation, which may negatively impact their capacity to carry out motor activities that are age-appropriate (Hilton & Ratcliff, 2022). 90% of kids with ASD have sensory processing issues, such as tactile hypersensitivity and other sensory modulation abnormalities, which may make it difficult for them to continue participating in the motor activities needed for learning (Trudel et al., 2022). The desired level of age-appropriate motor development is not attained (Hebert et al., 2022). Children with ASD may learn motor skills

differently than typically developing children due to social attention deficit (Hu et al., 2022), variations in observational learning (Drill & Bellini, 2022), and anomalies in executive function (Cavalli et al., 2022). It is advised to employ specific tactics, such as designing various workout programs, implementing, and providing feedback in children with ASD, to enhance the learning of motor skills. Strategies to assist the unique social communication, behavior, and interest patterns of children with ASD can be helpful. The use of exergames, hippotherapy, aquatherapy, and other motor activity and motor ability therapies in people with ASD has gained recognition as a particularly fascinating research field in recent years. The table presents studies looking at the impact of these interventions and motor learning variables on the acquisition, retention, and transfer of motor skills. (Table 1-6.)

Table 1. Outcomes of physical activity interventions (Motor Activity Intervention)

MOTOR ACTIVITY INTERVENTION								
Author(s) (year)	Study design, Strength of level of evidence	the evidence	Participants (Age range and diagnosis)	N	Intervention Description	Ratio (Instructor : Child)	Frequency / Duration	Conclusion
Arzoglou et al. (2013)	Non-randomized clinical trial/III	Weak	16y (mean), ASD	Total n=10 IG=5, CG=5	Traditional dance	1:1-2	34–45min, 3×/wk, 8wks	Children with ASD showed improvements in speed, agility, and body coordination after an 8-week traditional dance program.
Cei et al. (2017)	Prospective cohort/IV	Weak	6–13y, ASD	IG=30	Football training program	NR	60min, 2×/wk, 24wk	Children with ASD showed increased balance, rolling, running, and other motor skills after participating in a 6-month football program.
Guest et al. (2017)	Prospective cohort/IV	Weak	8–11y, ASD	IG=13	Multi-sport camp: locomotor and object control skills, then translational sports	1: 3	Full day, 5 days	Girls with ASD had better locomotor and object control skills after attending a 5-day multisport camp.
Zamani et al. (2017)	Non-randomized clinical trial/III	Weak	8–12y, ASD	Total n=30 IG=15 , CG=15	Gymnastic exercises	NR	45min, 3×/wk, 16wks	Compared to controls, children with ASD showed improvements in bilateral coordination, balance, and upper limb speed and agility after a 16-week gymnastics program.
Sarabzadeh et al. (2019)	RCT/II	Weak	6–12y, ASD	Total n=18	Tai Chi Chuan training	NR	60min, 3×/wk,	A 6-wk Tai Chi training resulted in improved

				IG=9, CG=9			6wks	balance and ball skills of children with ASD, compared to a control group.
Tabeshian et al. (2021)	Non-randomized clinical trial/III	Weak	9.6 y (mean), ASD	Total n=23 IG=11 , CG=1 2	Tai Chi Chuan Training	NR	60min, 3×/wk, 12wks	A 12-wk Tai Chi training resulted in improved non-Stereotypic behavior in the Tai Chi Chuan group. Since there was no discernible difference between the follow-up and the posttest, behavioral change was kept at that point.

ASD: autism spectrum disorder, CG: control group, IG: intervention group, min: minutes, mo: months, N: number, NR: not reported, RAS: rhythmic auditory stimulation, RCT: randomized clinical trial, TD: typically developing, wk(s): week(s), y: years.

Table 2. Outcomes of physical activity interventions (Motor Skill Interventions)

MOTOR SKILL INTERVENTIONS

Author(s) (year)	Study design	Strength of the evidence	Participants (Age range and diagnosis)	N	Intervention Description	Ratio (Instructor : Child)	Frequenc y / Duration	Conclusion
El Shemy and El-Sayed (2018)	RCT/II	Weak	8–10y, ASD	Total n=30 IG=12 , CG=1 5	Motor skills and gait training with auditory rhythmic cueing	NR	PT 60min, 3×/wk, 12wks; RAS 30min, 3×/wk, 12wks	Compared to a control group receiving only motor skill training, children with ASD had improved motor abilities after a 12-week program: motor skills and gait training intervention with rhythmic auditory stimulation.
Najafabadi et al. (2018)	RCT/II	Weak	5–12y, ASD	Total n=26 IG=12 , CG=1 4	Sports, play, and active	1:3	40min, 3×/wk, 12wks	Compared to controls, children with ASD showed improved balance after a 12-week motor skills program.
Bhat et al. (2022)	Non-randomized clinical trial/II	Adequate	5–15y, ASD	Total n=20 IG=10 , CG=1 0	Motor skill (locomotor, object control)	NR	40min, 2×/wk, 12wks	Gross motor skills were enhanced after a 12-week motor skills program. In kids with ASD, it was linked to social communication and functional deficits. ASD linguistic, cognitive, and functional impairments, as well as the intensity of repetitive behavior, were all correlated with five motor abilities.

ASD: autism spectrum disorder, CG: control group, IG: intervention group, min: minutes, mo: months, N: number, NR: not reported, RAS: rhythmic auditory stimulation, RCT: randomized clinical trial, TD: typically developing, wk(s): week(s), y: years.

Table 3. Outcomes of physical activity interventions (Hippotherapy and Equine-Assisted Interventions)

HIPPO THERAPY AND EQUINE-ASSISTED INTERVENTIONS								
Author(s) (year)	Study design, level of evidence	Strength of the evidence	Participants (Age range and diagnosis)	N	Intervention Description	Ratio (Instructor : Child)	Frequenc y / Duration	Conclusion
Borgi et al. (2016)	RCT/II	Weak	6–12y, ASD	Total n=28 IG=15 , CG=13	Equine assisted	1:3-4	60– 70min, 1×/wk, 24wks	When compared to a control group, a 6-month equine aided therapy program did not help children with ASD's motor abilities.
Gabriels et al. (2015)	RCT/II	Adequate	6–16y, ASD	Total n=116 IG=58 , CG=58	Hippotherapy	1:2-4	60min, 1×/wk, 10wks	Compared to a control group, children with ASD did not exhibit improved motor skills or praxis after a 10-week hippotherapy program.
Rezapour-Nasrabad et al. (2022)	RCT/II	Weak	8–13y, ASD	IG=16	Hippotherapy	1:1-2	45-60min, 1×/wk, 10wks	Comparing children with ASD to a control group, a 10-week program simulating horseback riding led to improvements in visual-motor control, body coordination/balance, reaction speed, strength, speed, and agility.

ASD: autism spectrum disorder, CG: control group, IG: intervention group, min: minutes, mo: months, N: number, NR: not reported, RAS: rhythmic auditory stimulation, RCT: randomized clinical trial, TD: typically developing, wk(s): week(s), y: years.

Table 4. Outcomes of physical activity interventions (Aquatic Interventions)

AQUATIC INTERVENTIONS								
Author(s) (year)	Study design, level of evidence	Strength of the evidence	Participants (Age range and diagnosis)	N	Intervention Description	Ratio (Instructor : Child)	Frequenc y / Duration	Conclusion
Caputo et al. (2018)	Non-randomized clinical trial/III	Weak	6–12y, ASD	Total n=26 IG=13, CG=13	Aquatic skills: emotional adaptation, swimming adaptation, social integration	1:1, 1:3	45min, 1– 2×/wk, 10mo	Children with ASD showed improvements in their motor and swimming skills after a 10-month aquatic program.
Alaniz et al. (2017)	Prospective cohort/IV	Weak	3–7y, ASD	IG=6	Aquatic skills	1:2	60min, 1×/wk, 16, 24wk	Children with ASD had 8, better swimming orabilities after an 8–24 week swim program.
Marzouki et al. (2022)	RCT/II	Adequate	6–7y, ASD	Total n=28 IG1=10, IG2=10, CG=8	Technical aquatic training, game- based aquatic training	1:2	50min, 2×/wk, wk	Compared to a control group, children with ASD showed improved stereotyped behaviors and gross motor skills after an 8-week aquatic exercise program.

ASD: autism spectrum disorder, CG: control group, IG: intervention group, min: minutes, mo: months, N: number, NR: not reported, RAS: rhythmic auditory stimulation, RCT: randomized clinical trial, TD: typically developing, wk(s): week(s), y: years.

Table 5. Outcomes of physical activity interventions (Exergaming Interventions)

EXERGAMING INTERVENTIONS								
Author(s) (year)	Study design, level of evidence	Strength of the evidence	Participants (Age range and diagnosis)	N	Intervention Description	Ratio (Instructor : Child)	Frequenc y / Duration	Conclusion
Edwards et al. (2017)	Prospective cohort/IV	Weak	6–10y, ASD and Typically developing	Total n=30 ASD=11, TD=19	Sports video games (Xbox Kinect)	NR	45–60min, 3×/wk, 2wks	When compared to a control group, a 2-week active video gaming program did not help children with ASD's golf or motor skills.
Travers et al. (2017)	Prospective cohort/IV	Weak	7–17y, ASD	IG=29	Balance video game (Xbox Kinect, Nintendo Wii)	NR	60min, 3×/wk, 6wks	Children with ASD had better balance after participating in a 6-week biofeedback-based video game balance training program.
Lau et al. (2020).	Prospective cohort/IV	Weak	8–18y, ASD	Total n=203 IG=125, CG=78	Sports video games (Xbox Kinect)	NR	30min, 1×/wk, 12wk	Children with ASD demonstrated increased strength, speed, and agility over a 12-week exergaming program.

ASD: autism spectrum disorder, CG: control group, IG: intervention group, min: minutes, mo: months, N: number, NR: not reported, RAS: rhythmic auditory stimulation, RCT: randomized clinical trial, TD: typically developing, wk(s): week(s), y: years.

Table 1. Outcomes of physical activity interventions (Effects of Motor Learning Variables on Motor Skill Acquisition, Retention, And Transfer)

EFFECTS OF MOTOR LEARNING VARIABLES ON MOTOR SKILL ACQUISITION, RETENTION, AND TRANSFER								
Author(s) (year)	Study design, level of evidence	Strength of the evidence	Participants (Age range and diagnosis)	N	Intervention Description	Ratio (Instructor : Child)	Frequenc y / Duration	Conclusion
Taheri-Torbati and Sotoodeh (2019)	RCT/II	Weak	9–13y, ASD and TD	Total n=48 IG1: ASD=12, TD=12; IG2: ASD=12, TD=12	Throwing task with video versus live modeling instruction	1:1	17 2days after 1wk	Children with ASD and children with typical development acquired an arm coordination pattern similarly after a 2-day throwing activity that alternated between film and live modeling.
Tse (2019)	RCT/II	Strong	9–12y, ASD	Total n=65 IG1=22, IG2=22, CG=21	Throwing task with internal versus external attention of focus	NR	1× with retention/ the next day	A throwing exercise with an internal focus compared to an external focus and no focus produced similar skill acquisition across all groups, but the internal focus group saw better retention and transfer of ASD children than the other groups did.
Baniasadi et al. (2022)	RCT/II	Weak	16–19y, ASD	Total n=48 IG1=16, IG2=16, CG=16	Basketball-shooting task	NR	1× with retention/ the next day	A modified basketball shooting task resulted in improved retention and transfer with instruction children with ASD.

ASD: autism spectrum disorder, CG: control group, IG: intervention group, min: minutes, mo: months, N: number, NR: not reported, RAS: rhythmic auditory stimulation, RCT: randomized clinical trial, TD: typically developing, wk(s): week(s), y: years.

DISCUSSION AND CONCLUSION

Participation in physical activity provides psychosocial improvements such as decreases in stress, anxiety and anxiety levels in individuals with autism, as well as increases in self-anxiety, socialization, self-confidence and sense of achievement (Menear & Neumeier, 2015). At the same time, participation in physical activity reduces the risk of death and disease in these individuals due to diseases such as diabetes, obesity, cardiopulmonary diseases; leads to increases in motor function, muscle strength and physical fitness levels (Zocante et al., 2021). There is no one-size-fits-all approach to determining and implementing exercise programs for individuals with ASD. Each individual may have different interests, proficiency and understanding of exercise. It is important to understand the individual with ASD as well as possible before starting the program. For instance, interventions to improve strength should adhere to the prescribed frequency, intensity, and duration of resistance training (Sowa & Meulenbroek, 2012). When working with children who have ASD, it is also advised that educators and medical professionals follow exercise guidelines and education programs (Shields et al., 2012). The goal of the intervention should be to alter at least one of the body's structures and functions, and experts should recommend an exercise and physical activity regimen.

It is well recognized that the mechanisms behind the acquisition and generalization of motor abilities in kids and adults with ASD differ from those in healthy people, necessitating the employment of various learning techniques for the best results (Moraes et al., 2017). Our results support the use of verbal and visual instructions to enhance the development of motor skills in ASD kids (Table 1.).

It is suggested that future research should concentrate on the efficiency of the teaching technique and types of feedback given the disparities in social communication of children with ASD (Zhao & Chen, 2018). Certain motor learning strategies may perform better or worse depending on the individual. Participants in research studies with ASD should be accurately

characterized. For planned activity practices, it is recommended that educators and clinicians take into account the principles of motor learning when providing. Depending on the person, some motor learning techniques may work better or worse. For planned activity practices, it is advised that educators and clinicians take into account the principles of motor learning when providing interventions to children with ASD and document the child's reaction to determine the effectiveness of the intervention. Participants in research studies with ASD should be accurately characterized (Shields et al., 2012).

The literature has offered a variety of specific recommendations to encourage children with ASD to engage in exercise and physical activity programs (Srinivasan et al., 2014). It is crucial for future research that the methods utilized to support children with ASD be thoroughly documented. Future studies are required to determine the efficacy of these methods for encouraging children with ASD to engage in physical activity. It is important to carefully assess and record the methods educators and clinicians employ to maximize their engagement in physical activity and exercise treatments (Srinivasan et al., 2014).

Physical activity and exercise programs have been shown to enhance some motor outcomes in children with ASD, including activity, body structure, and body function. (Table 1.). The general quality of this evidence is, however, poor. The study population should be thoroughly described, the sample size should be adequate, the intervention and control conditions should be characterized using guidelines and protocols, and the major outcome measures should be clearly defined and predicted to change as a result of the intervention. The impact of motor learning strategies on the development and transfer of motor skills in children with ASD is becoming more and more clear. The impact of physical activity and exercise interventions on social, behavioral, and cognitive skills will be clarified by more research in this field.

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Conflict of interests

The authors have no conflict of interests to declare. No financial support was received for this study.

Author Contributions

The entire work plan was performed by the author (Study Design; Data Collection; Data Interpretation; Manuscript Preparation; Literature Search)

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