

# Physical education of children with autism spectrum disorders: a systematic review of structure and effects of interventional programs

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## Abstract

**Introduction.** Studies of the effect of physical activity on indicators of physical and social health, as well as communication skills remain relevant owing to the lack of clear recommendations regarding the types, organization, and substantive content of sports and exercise interventional programs, as well as means of physical education (PE) effective for autism spectrum disorders (ASD) treatment and correction and improving the participants' quality of life.

**Methods.** The electronic databases of PubMed, LILACS, MEDLINE, Embase, and Google Scholar were searched. Co-authors analysed the articles in accordance with a checklist, developed their summary, and verified their accuracy. All the search results are relevant as of June 2019.

**Results.** In the scientific studies of 2000–2019 concerning the effect of applying PE programs for children with ASD, the participants were usually heterogeneous in age, level of functional capabilities, and intelligence quotient. The duration of the experiment was short (8–14 weeks); the frequency of interventions was different, the training sessions lasted 45–60 minutes. PE activities with proven effectiveness were swimming and water games, running, walking, imitation of riding, elements of yoga and oriental martial arts.

**Conclusions.** It is worth conducting a randomized study with a representative sample, within a group of the same age, intelligence quotient, daily physical activity, functional capabilities that would investigate indicators of all groups (physical, cognitive, behavioural, communicative) in an integrated manner, with a particular focus on those that are of interest to practice.

**Key words:** autism spectrum disorders, children, physical activity, program, quality of life

## Introduction

The number of children with autism spectrum disorders (ASD) increases each year [1, 2]. Recent population-based studies have found a high prevalence rate of ASD. It has also been reported that an average of 1% of children has ASD in the USA; in South Korean schools, the index equals 3.7% among males and 1.5% among females [2–4]. It is also emphasized that nearly 2/3 of medical cases remain undiagnosed and therefore do not receive any specialized help or services.

The term 'ASD' stands for a wide range of neurodevelopmental disorders that involve autism disorder, Asperger syndrome, Rett's disorder, childhood disintegrative disorder, and pervasive developmental disorder – not otherwise specified (PDD-NOS). The leading diagnostics features of ASD include limited communication skills, difficulties with social interaction, restrictive behaviour patterns, difficulties in the development of motor behaviour; the diagnosis of specific subtypes requires an overall understanding of cognitive abilities, speech, communication, as well as behavioural, social, and adaptive problems. Behavioural problems may consist in hyperactivity/inattention, aggression, obsessive-compulsive-like behaviours, and sleep disorders [2, 5]. Also, limited motor coordination, deficiencies in fine and gross motor functioning, repetitive, stereotypic movement in extraordinary/stressful situations are common.

Children with ASD tend to have an inadequate level of physical activity (PA) [6, 7]; they often present difficulties with

balance, posture stability, joint flexibility, and speed qualities development. Usually, this results in the occurrence of diseases, disharmonious physical development, and a low level of physical fitness [8–11]. Among the postponed effects of the reduced PA opportunities are a dangerously sedentary lifestyle, cardiovascular disease, obesity, insulin resistance syndrome, etc. People with ASD constitute a particular risk group, and PA may be a useful tool to prevent some of their health problems.

A special and well-designed system of physical education (PE) can be an effective way to reduce such risks and, therefore, to increase the level of physical fitness, as well as the child's psychomotor, cognitive, and emotional development. Nowadays, it is generally known that PE training and sports have a positive effect on indicators of mental and physical development, as well as children's physical fitness. The increasing number of physical exercises improves physical health, intellectual abilities, behavioural and social skills. Meta-analyses and studies have provided evidence that exercises determine improvement in muscular and cardiovascular endurance; they increase physical strength and flexibility of individuals with intellectual disability. However, much less is known on whether such correlations can be found in children with ASD and to what extent.

There are several meta-studies that confirm the positive effects of various means of PE on the performance of children with ASD, in particular, their cognitive development [12, 13], health indicators, behavioural problems (notably, indicators of aggressiveness and destructive behaviour) [13],

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motor skills, social skills [14], muscle strength and endurance [14], and disruptive behaviour (e.g. stereotypy and aggressive behaviour) [5].

Nowadays, there are several approaches to organizing PE for children with ASD. Some authors [15] are convinced that individual tasks are more significant in improving the psychophysical development and elaboration of social skills among children with ASD. However, in other studies [13], considerable improvements in the studied parameters were revealed during group training.

Research has shown that improved health, including some psychosocial indicators in children with ASD is a result of applying specific types of PA in the developed PE programs [12–15]. Running and swimming were the most common means of PE for this category of children [15]. At the same time, intensive PA brought about stronger effects [13] than training programs with a low level of PA. In general, the importance of PA for individuals with ASD has been confirmed in scientific papers, and the magnitude of the positive effects varies from medium to above average. There is evidence that in children with ASD, PE improves maladaptive behaviour patterns, communication skills, and academic engagement, although not all cognitive processes become enhanced [15].

ASD is a life-long condition; therefore, additional studies on the effect of PA on physical and social health indicators and communication skills remain relevant owing to the lack of clear recommendations regarding the types, organization, and content of sports and exercise interventional programs, as well as means of PE effective in ASD treatment and correction and in improving the program participants' quality of life.

The purpose of this review was to analyse PE programs aimed at correcting the problems of children with ASD, as well as to clarify their informative saturation and logic of construction. The review tasks were: (1) to describe the characteristics (participants, sample size, the availability of control group, etc.) and exercise interventions (type, duration of the program and individual sessions, etc.) of the included studies; (2) to analyse the purposes and effects of the interventional programs, identify their weak points, and determine the general features of programs with proven effectiveness.

## Subjects and methods

The search covered the electronic databases of PubMed, LILACS, MEDLINE, Embase, and Google Scholar. The following key words were used: 'Asperger,' 'autism,' 'ASD/autistic spectrum disorders,' 'pervasive developmental disorders/PDD-NOS'. These terms were paired with 'physical education,' 'physical culture,' 'physical exercise,' 'physical activity,' 'group exercise'. Selective Boolean operators 'AND' and 'OR' were applied. All the search results are relevant as of June 2019.

### Study selection and data extraction

A PRISMA diagram of the study selection process is provided in Figure 1. To be included into the analysis, the studies had to meet the following criteria: (1) reference solely to children with an ASD diagnosis; (2) the intervention description involving physical exercise, detailed content of the interventional programs, their ways of implementation, and effectiveness; (3) publication in the years of 2000–2019; (4) the full text of the article available in English. Exclusion criteria were as follows: (1) protocols with incomplete studies (a comment, an editorial, a letter); (2) studies related to other

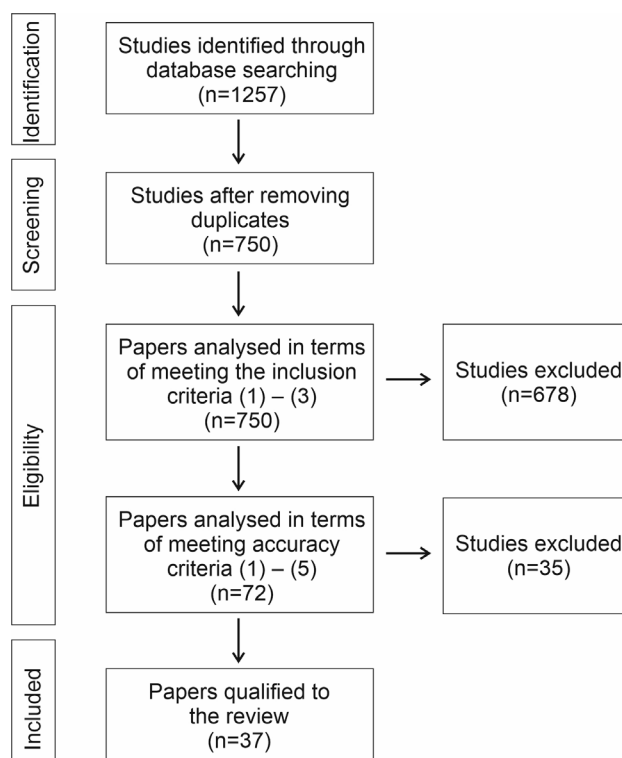


Figure 1. PRISMA flow diagram showing the selection of papers

diseases; (3) publications on the training of personnel who treat/study children with ASD or on the evaluation of their level of knowledge.

### Assessment of the quality of included studies

In order to ensure the accuracy of the review, the first and the second authors independently developed a summary of the included studies. The accuracy of these studies was checked by using a modified checklist with 5 questions as described by Lang et al. [5]: (1) Is there an accurate description of the participants? (2) Is there an accurate description of exercise behaviour being targeted? (3) Is there an accurate summary of the interventional program? (4) Is there an accurate description of outcomes? (5) Is there an accurate summary of the research methodology?

Co-authors analysed the articles in accordance with a checklist, developed their summary, and verified their accuracy. The resulting summaries were discussed, agreed on, and presented in Table 1.

### Ethical approval

The conducted research is not related to either human or animal use.

## Results

A total of 37 publications were selected as a result of the analysis of articles on examining the effect of PA among children with ASD for the period of 2000–2019 (Table 1).

The number of participants involved in the research varied significantly: from 1 person [16–18] or 2–3 people [19–24] up to 112 [25] in 1 group and 58 [26] or 64 [27] individuals in 2 groups. On average, 15 subjects were engaged in the research by specialists (mean [M]: 16.17; standard deviation [SD]: 18.44). The value of the standard error (higher than the arithmetic mean) confirms the wide scope of the number of participants.

Table 1. Characteristics of the included articles

Study	Groups	Participant characteristics			Interventional characteristics				Purpose (P) and effect (E) of the interventional program
		Sample size (n)	Age range (years)	Diagnosis	Duration (weeks)	Frequency (sessions/week)	Time (min)	Type	
Prupas and Reid, 2001 [34]	IG	4	5-9	Autism, fragile X syndrome	ND	5	10	Walk/jog sessions at a moderate intensity in early part of day. Three 10-min walk/jog sessions per day	P: Influence stereotypic behaviour and improve ability to learn E: Significant reduction of stereotypic behaviour
Bumin et al., 2003 [16]	IG	1♀	11	Stage III Rett syndrome	8	2	ND	Hydrotherapy (Halliwick method that includes adjustment to water, rotations, control of movement in water, and movement in water)	P: Improve functional activities and manipulative skills E: Decreased stereotypic movements, hyperactivity, anxiety; increased feeding activities, hand skills, walking balance, interaction with the environment
Lochbaum and Crews, 2003 [19]	IG1 IG2	3 2	16-21	Autism with mild mental retardation	6 6	3 2-3	20 60	Stationary cycling (65-70% of age-predicted HR maximum) Muscular strength program (60-80% of maximal lift weight)	P: Improve physical fitness E: Aerobic fitness increased over the 18 training sessions by 33%, 50%, and 33%; bench press increased by 19% and 28%; low row increased by 47% and 21%; and leg press increased by 29% and 12%
Yilmaz et al., 2004 [17]	IG	1	9	Autism	10	3	60	Swimming training (Halliwick method)	P: Improve physical fitness, physical development, behaviour E: Flexibility, cardiorespiratory endurance, balance, agility, power, upper and lower extremity and grip strength increased. The amount of stereotypic autistic movements decreased
Todd and Reid, 2006 [20]	IG	3♂	15-20	Autism	9 + 23	2	30	Weather dependent activities: snowshoeing, walking/jogging	P: Increase the number of circuits complete E: The number of circuits complete increased; decreasing verbal cues, encouragement, and directives given by school staff members during selected sessions of the snowshoe/walk/jog program
Pitetti et al., 2007 [36]	IG CG	3♂, 2♀ 3♂, 2♀	14-18 (16.6 ± 1.9) <sup>†</sup> 14-18 (17.4 ± 1.1)	ASD	36	2-5	8-20	PA classes + treadmill walking PA classes + leisure activity in campus	P: Decrease BMI E: Treadmill walking program was successful in achieving significant reductions in BMI in combination with an increase in caloric expenditure. Positive impact on exercise capacity
Bass et al., 2009 [29]	IG CG	17♂, 2♀ 12♂, 3♀	5-10 (6.95 ± 1.67) 4-10 (7.73 ± 1.65)	ASD	12	1	60	Horseback riding, horsemanship activities Wait list participants	P: Improve social functioning, sensory stimulation E: Improved sensory integration and directed attention; increased social motivation and sensory sensitivity; decreased inattention and distractibility
Garcia-Villamisar and Dattilo, 2010 [35]	IG CG	22♂, 15♀ 19♂, 15♀	17-39, 31-49 24-38, 30 6-9	ASD	52	5	120	Leisure program intended to facilitate interaction with media, engagement in exercise, playing games, doing crafts, attending events, and participating in other recreation activities Wait list	P: Improve life quality, decrease the level of stress E: Decrease in overall scores of stress levels, increase in the 4 measured factors of quality of life (satisfaction, independence, competence, social interaction) and the total score for quality of life
Pan, 2010 [44]	IG1 IG2	8♂ 8♂	6-9	ASD	10* + 10 10 + 10*	2	90	Swimming lessons	P: Obtain swimming skills, improve social behaviour E: Improved aquatic skills, potential for social improvements

	IG	3	4-5	Autism	ND	ND	ND	Swimming lessons		
Rogers et al., 2010 [21]	IG	30	6-8	Autism	20	2	60	Simulated developmental horse-riding program + regular occupational therapy	P: Teach fundamental swimming skills E: Development of swimming skills and language	
Wuang et al., 2010 [51]	CG	30			20			Regular occupational therapy	P: Design a horse-riding program; examine the program effectiveness in improving motor and sensory integrative functions of children with autism E: IG showed improved motor proficiency and sensory integrative functions; therapeutic effect sustained for at least 24 weeks	
Anderson-Hanley et al., 2011 [37]	IG1	12	10-18 (14.8 ± 2.7)	ASD	ND	ND	20	Exergaming, which combines physical and mental exercise by linking physical activity movements with video game control	P: Obtain potential behavioural and cognitive benefits of exergaming E: Repetitive behaviours significantly decreased	
	IG2	10	8-21 (13.2 ± 3.8)					Dance Dance Revolution game, cyber cycling		
Ennis, 2011 [38]	IG	6/11†	3-9	Autism	10	2	60	Aquatic program	P: Improve motor and social functioning E: Improved water-based skills and quality of life	
Fragala-Pinkham et al., 2011 [43]	IG	12	6-12	ASD, IQ in normal range	14	2	40	20-30 min of aerobic activities, 5-10 min of muscular strength and endurance training, and 5 min of cool-down and stretching activities	P: Improve swimming skills, cardiorespiratory endurance, muscular endurance, mobility skills, and participant and parent satisfaction E: Within-group improvements in swimming skills in IG. High program attendance. Parents and children very satisfied with the program activities and instructors, the level of socialization increased	
	CG	5			-	-	-	Wait list		
Hayakawa and Kobayashi, 2011 [52]	IG	23♂	16.9 ± 0.8	Autism	12	1	30	Walking movement, standing and walking balance, leg-hip extension, ipsilateral movement in a sitting position	P: Investigate the acceptance of using training machines by children with intellectual disabilities and the effect of training on their ability to exercise and their behaviour in daily life E: Machine training was effective for improving physical and psychological condition; training activated the athletic potential of children with intellectual disabilities	
Morrison et al., 2011 [40]	IG	2♂, 2♀	10-21	Autism	ND	ND	ND	3-component multiple-schedule sequences: an antecedent-exercise test sequence, a noncontingent leisure-item control sequence, and a social-interaction control sequence	P: Identify leisure and exercise items associated with high levels of engagement and low levels of problem behaviour E: Decreased problem behaviour	
Pan, 2011 [42]	IG	14	7-12 (8.55 ± 2.19)	ASD (50%) + non-ASD siblings	14	2	60	Aquatic intervention	P: Improve aquatic skills and physical fitness components E: Positive impact on the lifestyle and independence of individuals, especially those with disabilities; children with ASD can respond to a training stimulus as physical fitness components improved (especially muscular strength/endurance and more advanced aquatic skills)	
	CG	16								
Rosenblatt et al., 2011 [39]	IG	22♂, 2♀	3.6-16.5 (8.9 ± 3.6)	ASD	8	ND	45	Multimodal yoga, dance, and music therapy program	P: Investigate the interventional program impact on aggression, anxiety, attention problems, atypicality, conduct problems, depression, hyperactivity, somatization, withdrawal E: High efficacy in treating behavioural and some core features of autism, particularly in latency-age children	
Yanardag et al., 2011 [33]	IG	4♂	7-9	Autism	6	5	60	Tennis program	P: Teach basic tennis skills E: Increased basic tennis skills	
Bahrami et al., 2012 [32]	IG	13♂, 2♀	5-16 (9.13 ± 3.63)	ASD	14	4	30-90††	Kata techniques training: Heian Shodan (Shotokan) Kata	P: Effect of kata techniques training on stereotypic behaviours E: Stereotypy decreased by 42.54% from baseline levels across IG participants	
	CG	13♂, 2♀			-	-	-	Non-training		
Chan et al., 2013 [28]	IG	20 (95%♂)	6-17 (11.28 ± 3.90)	ASD	4	2	60	Nei Yang Gong set comprising 5 types of movement: tranquil stand, shoulder relaxation, nasal bridge massage, qi-circulating movement, and passive Dan Tian breathing	P: Effect of mind-body exercise on self-control problems, such as emotional outburst, repetitive or obsessive thoughts or acts, and impulsivity E: Increased self-control; decreased temper outbursts, obsessive behaviours, and verbal expression problem	
	CG	20 (85%♂)	6-17 (12.42 ± 3.25)					Muscle relaxation		

Yanardag et al., 2013 [22]	IG	2♂, 1♀	6-8	Autism	12	3	60	Aquatic play skills intervention and aquatic exercise training + video prompting procedure	P: Determine the effectiveness of video prompting on aquatic play skills E: Participants increased their correct target skills, improved motor performance
Arzoglou et al., 2013 [48]	IG	5	16.8 ± 1.8)	Autism	8	3	35-45	Program of traditional dances	P: Evaluate the effect of a structured program of traditional dances on neuromuscular coordination of individuals with autism
	CG	5	16.6 ± 1.3)					Physical education program at school	E: Improved neuromuscular coordination, balance, walking backwards, jumping over an obstacle on one foot, lateral jumps right and left, lateral movement, and repositioning
Neely et al., 2014 [23]	IG	1♂, 1♀	7-8	ASD	10-12	2-3	10	Jumping on indoor trampoline	P: Effect of exercises on stereotypic behaviour and academic engagement E: Benefit from physical exercise prior to academic instruction; reduction of stereotypy
	IG	49♂, 9♀	6-16 (10.5 ± 3.2)	ASD	10	ND	45	Therapeutic horseback riding intervention	P: Evaluate if therapeutic horseback riding could significantly improve measures of self-regulation, communication, social, adaptive, and motor behaviours E: Decreased irritability and hyperactivity; improved social cognition and communication
Gabriels et al., 2015 [26]	CG	52♂, 6♀	6-16 (10.0 ± 2.7)						
	IG	5♂, 5♀	12.3 ± 2.6)	ASD	ND	ND	ND	Stationary bicycle exercise intervention (self-selected pedalling rate)	P: Effect of exercise on cognitive and motor functioning E: Significant improvements in participants' inhibition, cognitive planning, and set-switching
Ringenbach et al., 2015 [41]	IG	13♂, 2♀	5-16 (9.20 ± 3.32)	ASD	14	4	30-90 <sup>††</sup>	Karate techniques training (kata sessions)	P: Use of karate techniques training to improve communication deficit E: Reduced communication deficit of children with ASD
	CG	13♂, 2♀	5-16 (9.06 ± 3.33)		-	-	-	No formal physical exercises	
	CG	11						Conventional therapy	
De Milander et al., 2016 [24]	IG	1♀, 1♂	9, 8	ASD	10	1	30	Equine riding combined with various fundamental movements, such as manipulation and stability skills	P: Explore the interventional program efficiency, improve motor functional level E: Improved balance, upper-limb coordination and strength as aspects of motor proficiency
	IG	8♂	8-14 (10.2 ± 2.38)	ASD	8	2	50	Taekwondo interventional program	P: Decrease postural sway during static balance tasks following an 8-week taekwondo training program; reduce the time spent to complete functional balance tasks E: Improved postural control; high adherence to the taekwondo sessions (92.3%); participants and their parents enjoyed the sessions and activity
Kim et al., 2016 [46]	CG	5♂, 1♀	8-14 (10.00 ± 2.83)		-	-	-	No intervention	
	IG	11♂	6-12 (9.68 ± 1.61)	ASD	12	2	70	Table tennis exercises, group games	P: Effects of physical activity intervention on motor skill proficiency and executive function E: Improved motor skills, manual coordination (body coordination, strength, agility, total motor composite), executive function
Pan et al., 2017 [50]	CG	11♂	6-12 (8.49 ± 1.76)		-	-	-	No intervention	
	IG	1♂	11	ASD	ND	ND	ND	Behavioural skills training for learning skateboarding steps	P: Evaluate the effects of behavioural skills training in teaching a child with ASD how to correctly engage in a series of skateboarding skills E: The majority of skateboarding skills successfully acquired and maintained after training and in alternate settings
Thomas et al., 2016 [18]	IG	36	6-16	ASD	10	ND	45	Therapeutic horseback riding intervention	P: Investigate if behavioural, social, and communication improvements remained 6 months after completion of therapeutic horseback riding E: Reductions in irritability behaviour at a 0.1 level, therapeutic horseback riding group sustained significant initial improvements in social and communication behaviours, along with the number of words and different words spoken in a standard language sample
	CG	28			-	-	-	No horse contact	
Gabriels et al., 2018 [53]	IG	46	6-12	ASD	48	2	40	Physical activity program: basic coordination and strength exercises	P: Examine the effects of exercise-based intervention on weight status, metabolic profile, ASD symptoms profile, and parent-perceived quality of life in children with ASD E: In IG, significant positive effects in metabolic health (high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and total cholesterol), reduced autistic traits, improved parent-perceived quality of life
	CG	18	6-12		-	-	-	Usual levels of daily activity, without additional exercise components	

Yu et al., 2018 [25]	IG	112	4-6	ASD	16	2	60	Game-based exercise training program, 6-8 stations set up and children instructed to finish the exercises in all stations one after another in a fixed order	P: Test the effectiveness of a supervised game-based exercise training program in promoting motor skills and physical fitness, as well as reducing stereotypic and maladaptive behaviours in preschool children E: ND
	CG							Wait list; maintaining normal physical activities	
Zamani-Jam et al., 2018 [49]	IG	8♂, 7♀	8-12 (10.2)	ASD	16	3	46	Gymnastic exercises	P: Impact of program on motor development (speed of running and agility, balance, bilateral coordination and strength, speed of reaction, response, visual-motor control, speed and agility of the upper limb) and neuropsychological skills, including attention, executive functions, sensory and motor functions, language functions, and memory and learning functions E: Improved motor and neuropsychological skills
	CG	9♂, 6♀	8-12 (10.12)					Daily activities	
Zhao and Chen, 2018 [47]	IG	14♂, 7♀	5-8 (6.14 ± 0.96)	ASD	12	2	60	Structured physical activity program based on guidelines and recommendations for children with ASD	P: Improve social interaction and communication skills E: Special structured physical activity program positively influenced social interaction and communication skills, prompt response, and frequency of expression
	CG	15♂, 5♀	5-8 (6.10 ± 0.98)					Regular physical activity	
Kwon et al., 2019 [30]	IG	18	6-13	ASD	8	1	30	Therapeutic horseback riding	P: Investigate if therapeutic horseback riding could improve language skills and cognitive function of children with ASD E: Statistically significant improvements in receptive and expressive language. No statistically significant differences in language or cognitive abilities
	CG								

IG – intervention group, CG – control group, ASD – autism spectrum disorder, IQ – intelligence quotient, ND – not determined, HR – heart rate, PA – physical activity, BMI – body mass index  
\* weeks with treatment, † only 6 persons completed at least 1 of 10 full weeks, ‡ mean (standard deviation), †† 30 minutes at start, 90 minutes after 8 weeks

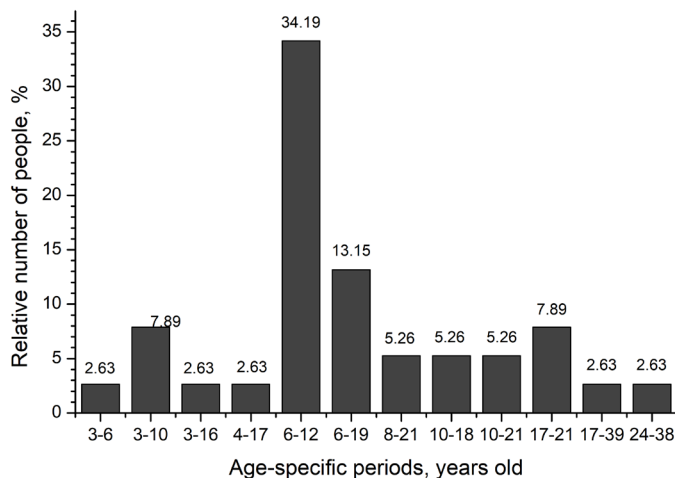


Figure 2. Proportions (%) of subjects with autism spectrum disorders of different age ranges in the included studies (n = 37)

The contingent of test subjects (84.2%) usually consisted of school-age children. In every third case (34.2%), children aged 6–12 years were involved in the research (Figure 2). The age of the participants ranged from 3 to 39 years; quite often, heterogeneous age groups were formed. Individuals of different ages were frequently engaged in one group of the PE program; in particular, 57.9% of the articles concerned children of primary, secondary, and senior school age, as well as adults.

The duration of PE programs ranged from 4 [28] up to 48 weeks [27, 28] and equalled 13.55 (SD: 10.70) weeks on average. The duration of the main part of the analysed programs (63.2%) did not exceed 8–14 weeks (M: 10 weeks).

The frequency of training in experimental programs amounted to 2.57 (SD: 1.14) times/week, but also has fluctuated significantly – from 1 time/week [24, 29, 30] up to 4–5 times/week (kata studying, cycling [31, 32], tennis lessons [33], walking in alternation with jogging [34], outdoor activities [35]).

In 21% of the analysed works, the duration of the training lessons was not indicated; however, in accordance with the information available, it can be concluded that usually they lasted for 45–60 minutes (M: 50.20 min; SD: 21.18 min; median: 60 min; maximum: 120 min; minimum: 10 min). The duration of a lesson with a stationary bike, walking on a treadmill, walking in alternation with jogging, exergaming sessions did not exceed 20 minutes [19, 34, 36, 37]. In rare cases, e.g. training in karate technique, the sessions lasted up to 1.5 hours [31, 32]. Recreational classes were 2 hours long [29].

Few interventional programs [17, 18, 20–25, 33, 38–41] did not involve a control group, which allows to consider them insufficiently substantiated. There is practically no information on the intensity of the physical load applied, the intelligence quotient (IQ) level of children involved in the examination, the volume of PA, or the level of the participants' functional capabilities.

A significant part of the works studied the effects of water exercises [16, 22, 38, 42, 43]. It was proved that hydrotherapy had a positive effect on the technical skills of people with ASD (e.g. on the formation of new skills [42–44]) and increased physical fitness levels (in particular, leg and hand strength, flexibility, cardiorespiratory endurance, balancing, and dexterity [42, 43]). Water exercises exerted a positive impact on the behaviour of ASD individuals and their interaction with others [34, 36]; a decrease in hyperactivity, anxiety, and stereotypy was also observed [34, 42, 44]. Physical exercises

in water positively influenced various indicators of quality of life, in particular, those of physical, emotional, social, and school functioning.

Hippotherapy training courses [26, 29] turned out useful to improve motor skills, reduce the number of stereotypies and mood disorders, increase self-regulation and socialization [26], strengthen social motivation, reduce sensory sensitivity, overcome and correct absent-mindedness, increase concentration, boost fine motor skills [26, 29], as well as improve communication skills [26] of children with ASD.

The use of yoga and martial arts had a positive effect on stereotypic behaviour [32, 33], overcoming difficulties with communication [31, 33], interaction with others [39, 45], improving some physical fitness indicators (enhancing balance while standing on one and two legs) [46].

Cycling positively affected repetitive behaviour, cognitive functions, attentiveness, switching, perception, suppression, and executive functions [37, 41]; it also enhanced cognitive planning [42].

Positive effects were observed under the influence of exercises that required complex coordination. So, the researchers found out a positive impact of skateboarding on the formation of new motor skills [18]. Scientists proved positive results of dancing on repetitive behaviour, cognitive functions, executive function [37], behavioural problems [39], physical fitness, and motor skills [47, 48] of children with ASD. The effect of gymnastics exercises on self-control [28, 49], speech development [49], and physical fitness indicators [49] were also established.

Exercise programs involving cardio and strength fitness significantly increased the level of physical fitness in children with ASD; they primarily improved aerobic endurance and muscle strength [19]. The use of exergaming reduced the number of actions with stereotypic behaviour, improved cognitive and executive functions of children with ASD [37]. The application of outdoor games, as well as training programs with the priority usage of elements of sports games increased PA [50] and positively affected the motor abilities of children with ASD: hand and body coordination, strength and dexterity [22, 33, 50]; it also improved executive function [22].

## Discussion

The results of the analysis showed that in years 2000–2019, the number of studies on the effect of PE classes in children with ASD gradually increased. This is a consequence of a real rise in researchers' interest in this topic, since the use of physical exercises for therapeutic purposes is economically advantageous, has no contraindications [54–56], and comprehensively affects a wide range of indicators, including those reflecting the main development problems of children with ASD.

Despite the significant amount of scientific research held over the past 20 years, evidence of the positive effect of PA on overcoming manifestations of problematic behaviour and improving the psycho-functional state of children with ASD remains limited [57–60]. In the period of 2000–2019, most of the studies were conducted for the age group of 6–21 years. Our data indicate a wide range of ages of participants in pedagogical experiments, and thus confirm the results of other researchers who noted that the age of experiment subjects ranged from 4 to 27 years [13] and from 3 to 41 years [5]. Owing to the heterogeneity of the contingent, the conclusions of most scientific articles should be clarified.

At the same time, there is a lack of scientific research that would study various groups of indicators (physical, cognitive, and indicators of problematic areas in children with ASD: behavioural and communicative ones) as a whole. This does not allow finding out the leading ones for accented development.

It is worth noting that the existing studies were often heterogeneous, not only in terms of the participants' age but also with regard to their IQ levels, the volume of their daily PA, and their functional capabilities. Because of the limited overall number of children with ASD, scientists often combine investigations of children of related age ranges into a single group, which is unacceptable for research among children without ASD. Also, the subjects' IQ level was often not indicated, although such information is essential in interpreting numerous indicators. For example, more than 50% of children with ASD may achieve poor results during testing, not as a result of insufficient levels of PA, but because of inconsistencies or lack of understanding of the instructions [61, 62]. Authors usually do not indicate the level of children's functional capabilities, although there is information on large differences in the volume of PA [13, 63] among children with ASD and the related capabilities of such children, which can lead to significant functional differences. Children with ASD can significantly lag behind their peers in many other indicators, too [8, 25, 64–66]. Therefore, in research results analyses, they must be clustered to form more homogeneous samples [67–69].

Unfortunately, detailed information on the specifics of interventions for children with ASD, such as training intensity, volume, and frequency, was also mostly absent in publications for the period of 2000–2019. The intensity of the physical load was referred to only in individual studies, which does not allow exactly reproducing the training programs in practice and achieving the desired effect.

According to our data, PA programs lasted 4–48 weeks, but in most cases (60%) they were short-term and did not exceed 8–14 weeks. Often, the delayed effects were not studied. It was found that the frequency of intervention was 3 times/week on average, with sessions lasting for 60 minutes (minimum of 10 minutes, up to 120 minutes as maximum). This partially confirms the results described in specialist literature that the duration of interventions varies from 8 to 36 weeks, with a frequency of training classes of 2–3 times/week and the duration of the exercise sessions of 20–40 minutes [70]. So, training classes held 3 times/week for 45–60 minutes each, applied for 8 weeks within a program that provides for an integrated use of PE, can have a significant effect.

There were some reservations that the duration of positive effects after physical exercises was estimated by specialists infrequently and in small samples. Indeed, the positive effects of applying physical exercises may be temporary [5]. In such cases, in order to consolidate the effect, experts [34] have recommended conducting several physical exercises a day.

The results of our analysis confirm the observations from numerous studies on the effectiveness of water exercises, as well as running or walking [15]. However, for the first time, we proved the increased interest of researchers in studying the effectiveness of hippotherapy and martial arts for solving the problems of children with ASD.

The analysis of the obtained data shows that most researchers studied the influence of PE programs using one type of PA. Only some of them concerned verifying the effectiveness of comprehensive programs that used a wide

range of tools. For example, we examined the effectiveness of a relaxation exercise program with dance and music therapy tools [39], programs containing various types of exercises [40], training programs involving coordination and strength exercises [27], structured PA programs with naturally integrated elements of social interaction [53]. Some studies compared the effectiveness of two different programs: e.g. weight training and cardio fitness [19], yoga and Chinese gymnastics [28], one-time or three-time jogging loads [34], dance and exercise bike exergaming [37], or even three training programs: assistive bicycle therapy, cycling, and overall absence of cyclic applications [41].

The obtained results indicate that scientists usually studied only 1 or 2 indicators of 1, rarely 2 sets (physical, cognitive, and indicators of problem areas of children with ASD: behavioural and communicative ones), while there are only a few complex multidisciplinary studies in the area. The frequency of studies of communicative and cognitive indicators sets (12% and 10%, respectively) significantly ( $p < 0.05$ ) lags behind the frequency of studies of physical and behavioural indicators in children with ASD (35% and 31%, respectively). The popularity of studying these indicators is associated with the high social significance of such treatment goals and the critical importance of reducing harmful behaviour [13]. Our results are in line with data [13] stating that the most significant effect is observed by scientists in terms of physical development and physical fitness, and slightly less substantial results are found with reference to stereotypic and self-harming behaviour. Low evidence of PA exposure was noted in cognitive performance for adolescents, executive function (e.g. working memory, cognitive control, and attention), as well as better behavioural control (e.g. reduced aggression and disruptive behaviour) [13].

Data on changes in quality of life (4%), the volume of PA (3%), and body weight (4%) in children with ASD are scarce and contradictory. At the same time, there is a lack of scientific research that would study different sets of indicators in an integrated manner.

## Conclusions

1. The scientific research in the period of 2000–2019 devoted to the shifting effect of applied PE programs for children with autism usually included an age-heterogeneous contingent, corresponding to the level of children's functionality and their IQ level. The number of individuals involved in the research varied significantly (from 1 person up to 112). The population of test subjects (84.2%) usually consisted of school-age children; in every third case, children aged 6–12 years took part in the research.

2. The duration of the experiments was small: up to 8–14 weeks; the frequency of interventions differed, but usually equalled 3 times/week. Classes lasted for 45–60 minutes (but their duration varied greatly: from 10 up to 120 minutes). Therefore, it can be assumed that an experimental program could have a significant effect with a duration of 8 weeks and with training classes held 3 times/week, with several exercises per day lasting 45–60 minutes each, and a clearly fixed volume and intensity of the program involving complex application of PE means with proven efficiency (swimming and playing in water, running, walking, as well as imitation of riding, elements of yoga and oriental martial arts).

3. It is worth conducting a randomized study with a representative sample, among a contingent of the same age, IQ level, functional capacity, and daily PA application. The study should preferably include indicators of all groups (physi-

cal, cognitive, behavioural, and communicative ones) in an integrated manner, paying particular attention to those that are of interest for practice (quality of life, body weight, etc.) but have been infrequently investigated. The duration of the positive effects of physical exercise should be evidenced.

## Disclosure statement

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## Conflict of interest

The authors state no conflict of interest.

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