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ORIGINAL PAPER

Effects of Physical Exercise on Gross Motor Skills in Children with Autism Spectrum Disorder

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Abstract

Research shows many positive effects from physical exercise. The present study examined the impact of a structured physical exercise program compared to treatment as usual on the gross motor skills of children diagnosed with autism spectrum disorder (ASD). Participants included 20 children, from 4 to 7 years old, who were assigned to two groups; an experimental group ($n = 10$) who received a structured physical exercise program for 60-min sessions, three times a week for eight weeks, and a control group ($n = 10$) who received conventional physiotherapy. Gross motor skills were assessed with the Abbreviated Development Scale -3 before and after the physical exercise program. The experimental group exhibited significant improvements in gross motor skills compared to the control group. This study suggests that structured physical exercise programs can improve gross motor skills in children with ASD.

Keywords Autism spectrum disorder · Exercise · Physiotherapy · Motor skills · Specialized physical therapy

Introduction

Autism spectrum disorder (ASD) refers to a range of conditions characterized by challenges in social interaction, communication, and atypical patterns of activity and behaviors such as difficulties transitioning, intense focus on details, and peculiar responses to stimuli (American Psychiatric Association, 2013; Lombardo & Mandelli, 2022; Minsalud, 2015; Pan et al., 2009; World Health Organization, 2022).

Approximately 1 in 100 children globally has an ASD diagnosis (World Health Organization, 2022; Zeidan et al., 2022). In the United States, the overall prevalence rate of ASD was 23.0 per 1000 (1 in 44) 8-year-old children have ASD (Maenner et al., 2021).

While 16% of Colombian children under 15 years old are diagnosed with developmental disorders, there is no official data on the prevalence of ASD in Colombia (Minsalud, 2015).

The global scenario has prompted researchers to focus on the issue of delayed fundamental motor skills in children with autism spectrum disorder (ASD). Several studies (Gabis et al., 2020; Gandotra et al., 2020; MacDonald et al., 2013; Mache & Todd, 2016; Pusponegoro et al., 2016) have highlighted this issue, leading to increased attention and research efforts aimed at identifying definitive motor markers of ASD (MacDonald et al., 2013).

Additionally, several studies (Lourenço et al., 2020; MacDonald et al., 2013; Mache & Todd, 2016) have identified markers of late development in children with ASD, including gait, postural control, balance, coordination, strength, and motor planning delays in complex motor actions and skills (Pusponegoro et al., 2016).

Additionally, Qiu et al. (2010) argue that delays in motor development in children with ASD may be due to differences in the cerebellar circuits, the right basal ganglia, and parallel

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frontal-subcortical regions between autistic and non-autistic individuals. Consequently, this results in the poor acquisition of motor, social, and communicative skills. However, (Larbán et al., 2012; Vanvuchelen et al., 2007) point out that some motor system disorders, especially in organization and planning, are associated with the lack of development of the mirror neuron system, on the one hand, and perceptual alterations, on the other, that limit the capacity for imitation, leading to a lack of association between their movements and those they see in others.

Other studies have shown that physical exercise generates a neuroprotective effect on cerebral cortex activity. Exercise has been demonstrated to enhance the capacity for complex learning through plasticity and neuro-restoration (Ballesteros et al., 2022; Won et al., 2021), leading to improved cognitive and behavioral performance in children. When performed in a directed, continuous, and repeated manner, physical exercise is considered a potent and effective therapeutic tool for behavior management (Bowling et al., 2017; Luque, 2016).

A crucial principle in physical exercise for children is play. Hence, it is vital that the activities are done in a playful manner, promote a healthy lifestyle, enhance sensorimotor skills, and most importantly, allow children to enhance their socio-emotional skills and autonomy.

Intervention programs have become crucial in treating ASD, with a focus on addressing core characteristics such as socialization difficulties and restrictive behavior patterns (Busti et al., 2020). However, an increasing number of studies emphasize the significance of rehabilitation programs that target motor skills, particularly object control and locomotor skills. Several programs have shown a significant impact on the motor development of children with ASD, including aquatic therapy (Battaglia et al., 2019; Marzouki et al., 2022), yoga (Gulati et al., 2020; Kalaichandran et al., 2021), Tai Chi Chuan training (Sarabzadeh et al., 2019), programs based on sensory integration theory (Abdel & Mohammed, 2015) applied behavior analysis, as well as a wide range of programs based on physical activity (Arslan et al., 2020; Badi' ah et al., 2021; Colebourn et al., 2017; Ferguson et al., 2010; Hassani et al., 2020; Ketcheson et al., 2017, 2018, 2021; Langdon & Schlote, 2015; Lee et al., 2020; Šišková et al., 2020). In contrast, some programs, such as those based on active video games with Xbox Kinect, have failed to produce the expected results (Edwards et al., 2017).

Similarly, research collected from the past ten years indicates that physical activity can lead to the development of locomotor skills, improved aerobic capacity, gross motor function, functional skills, skill-related fitness, social functioning, and increased muscle strength and endurance in children with ASD (Arslan et al., 2020; Downey & Rapport, 2012; Healy et al., 2018; Langdon & Schlote, 2015). However, there is still no consensus on the best intervention model for this population when it comes to exercise (Ferreira & Loyacono, 2021; Ferreira et al., 2018).

Gómez et al. (2008) suggest a structure for physical exercise programs for children with ASD based on principles of individualization, integration, and normalization through diverse and enriched activities. These programs should have concise feedback, careful planning, and consist of an initial "warm-up" or "motor readiness" component followed by well-structured and interconnected "circuits" stations. This approach is recommended by literature as the best option, as it includes skills such as waiting, collaboration, continuous challenge, clear beginning and end, and rules. Additionally, these programs have been shown to be cost-effective as they require limited resources for implementation (Fessia et al., 2018).

Sánchez and Ordoñez (2019) found that physical activity as an intervention strategy shows improvements in gait, balance, coordination, physical fitness, motor planning, attention levels, concentration, and the reduction of aggressive and stereotyped behaviors through the implementation of games, walks, swimming, aerobics, jumping jacks, circuits, bikes, and yoga.

Therefore, the objective of the present study was to determine the effects of a (novel) physical exercise program on the gross motor skills of children with ASD.

Methods

Participants

The children participating in the study were recruited from the neurological rehabilitation centers in Neiva, Colombia. The parents of the eligible children were invited to a meeting where they received information about the project and were given the opportunity to decide whether to participate. Only 40 out of the total population of children with ASD met the inclusion criteria: a medical diagnosis of ASD, no concurrent medical conditions that hinder physical exercise, an age range between 4 and 7 years, and parents' acceptance of participation and signed informed consent. It should be noted that 20 children were excluded from the study due to additional unmet criteria (as shown in Fig. 1).

Instruments

A survey of sociodemographic, prenatal, perinatal, and postnatal antecedents was administered to the parents of the participating children. The survey had been previously subjected to expert judgment and a pilot study. To evaluate gross motor skills, the third version of the Abbreviated Development Scale (EAD-3) was used (Minsalud, 2016).

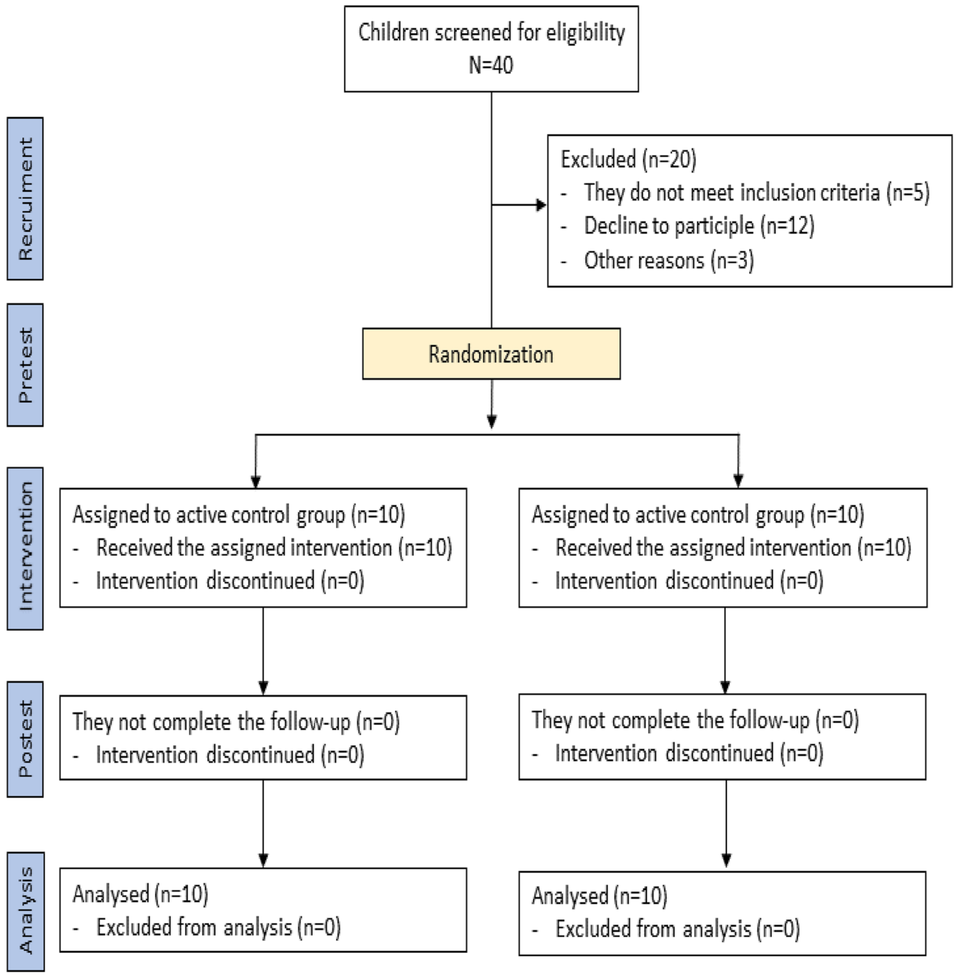

Fig. 1 Flowchart of the study

The EAD-1 was designed and validated in 1991 by the Colombian Ministry of Health and a team of health professionals. It is a free and easily accessible instrument that has been updated to its third version, EAD-3, which offers the examiner a valid and reliable tool for administration, qualification, and interpretation.

The Abbreviated Development Scale (EAD-1) was designed and validated in 1991 by the Colombian Ministry of Health and a team of health professionals to evaluate the development of Spanish-speaking Colombian children from birth to 7 years of age. The scale was created to provide health professionals with a simple and accessible tool to identify early risks of developmental delays. The EAD-1 has since been updated to its third version (EAD-3), which offers a mechanism for administration with convergent validity and reproducibility, making it a reliable tool for health professionals.

The EAD-3 scale has been constructed based on other globally recognized instruments such as the Griffiths, Battelle, Denver, Kent, Corman and Escalona, and Uzguiris-Hunt scales (Minsalud, 2016). Briefly speaking, it evaluates four areas of development: gross motor skills, fine-adaptive motor skills, listening-language, and personal-social; each area consists of 36 items for a total of 144, divided into 12 age ranges. In version 1, this instrument has been previously implemented in studies with Colombian children with ASD from 4 to 12 years of age. Most of the findings report deficient levels in those subjects' motor skills, the notion of the body and balance, and the maintenance of normal parameters in the tonicity factor (Crissien-Quiroz et al., 2017).

The evaluation of activities on the EAD-3 scale is performed by observing the subject's ability to perform each activity. The procedure for evaluating children's development with the EAD-3 involves three steps: first, the direct score is calculated based on the number of approved items; second, the direct score is transformed into a standard score to determine the subject's level of development; finally, the standard score is compared with expected scores for a particular age, using scales that are updated and specific to the Colombian context.

According to the EAD-3 scale, the children's age is classified through ranges from 1 to 12, and according to each range, the activities that the child must carry out during the evaluation are structured. See Table 1.

Table 1 Subscale gross motor skills items

Age rank	Items	Activity
1 0 days–1 month 0 days	1	Performs search reflex and suction reflex
	2	The Moro reflex is present and symmetrical
	3	Moves his limbs
2 1 month and 1 day–3 months and 0 days	4	Holds his head when lifting himself with his arms
	5	Raises his head and his chest is prone
	6	Turns his head from the midline
3 3 months and 1 day–6 months and 0 days	7	Controls his head when seated with help
	8	Flips
	9	Maintains seated position momentarily
4 6 months and 1 day–9 months and 0 days	10	Stays seated without help
	11	Adopts a sitting position
	12	Crawls in the prone position
5 9 months and 1 day–12 months and 0 days	13	Crawls with cross displacement (alternating knees and hands)
	14	Adopts a bipedal position and stands with help
	15	Stands without help
6 12 months and 1 day–18 months and 0 days	16	Stands up without help
	17	Takes steps on his own
	18	Walks in cross-scrolling without support (alternating hands and feet)
7 18 months and 1 day–24 months and 0 days	19	Runs
	20	Throws the ball
	21	Kicks the ball
8 2–3 years (24 months and 1 day–36 months and 0 days)	22	Jumps with both feet at the same time
	23	Steps on both feet
	24	Climbs two steps without support
9 3–4 years (36 months and 1 day–48 months and 0 days)	25	Walks on tiptoes
	26	Stands on one foot
	27	Goes down two steps with minimal support, alternating feet
10 4–5 years (48 months and 1 day–60 months and 0 days)	28	Walk in a straight line without visual support
	29	Jump three or more times on one foot
	30	Bounces and grabs the ball
11 5–6 years (60 months and 1 day–72 months and 0 days)	31	Jumping alternating feet Plays horsey
	32	Jumps from side to side on a line with his feet together
	33	Jumps moving with both feet
12 6–7 years (72 months and 1 day–84 months and 0 days)	34	Maintains balance at the tip of the feet with eyes closed
	35	Performs alternating jumps in sequence
	36	Performs some motor integration activity

Source: Minsalud (2016). Abbreviated developmental scale-3

What is more, the scale allows differentiation of each child's level of development into three categories based on the direct score: (1) the expected development depending on age, which is understood as an appropriate level for the subject in a certain period; (2) the risk of developmental problems, that is, the subject has not reached the expected level for his age in some areas of development; (3) deducing developmental problems, which is translated into a high probability of a subject's delay in some areas of development.

For the present study, the gross motor skills sub-scale was utilized, which consisted of 36 items and associated activities. The participants were aged between 4 and 7 years, with a range of 10, 11, and 12 years, as shown in Table 1.

The participating children's gross motor skills were evaluated independently before and after the intervention program. To avoid any biases, the evaluations were conducted by a neutral evaluator who was not involved in the design or implementation of the physical exercise program.

Fig. 2 Context in which the exercise program was developed

Intervention

The design of the physical exercise program was carried out through repeated circuits that consist of a series of exercises that are developed sequentially and in progressive complexity in workstations. This study structured the program into five stations, including activities to enhance gross motor skills such as running, jumping, throwing, kicking, and climbing. These activities included running in a straight line, jumping hoops, throwing, and kicking balls, and performing motor integration activities (refer to Fig. 2). The program aimed to improve the participants' gross motor skills in children aged 4–7 years old.

Following some theoretical guidelines, like those of Gómez et al. (2008), a physiotherapist who specialized in comprehensive sports intervention designed the physical exercise program. Once the physical exercise program was designed, it was submitted for review by three experts in the area. The experts gave a favorable opinion on the structure and feasibility of the program, considering the frequency, intensity, and exercises proposed through circuits that met the purpose of the study.

A pilot test was carried out with two 6-year-old children diagnosed with ASD to examine the acceptance and satisfaction of children and parents. The results made it possible to verify that the structure of the exercise program included the establishment of adequate recovery and hydration times, based on the consideration that these children tire easily, both physically and mentally.

It is essential to clarify that a structured, highly predictable, stable, and safe environment was selected that parents and caregivers could observe and monitor (Fig. 2).

The experimental group of children participated in a physical exercise program that was administered three times a week for a total of 24 sessions over the course of eight weeks. Each session lasted 60 min and was conducted in the morning hours, with the children's parents observing the procedures. On the other hand, the control group of children received their usual individual conventional physiotherapy as prescribed by the neurorehabilitation center they regularly attended. See Table 2.

Table 2 Application time

Phases	Time (min)	Activities
Warm-up phase	10	Joint mobility—stretching
Central phase	40	Five stations circuit
Cooldown	10	Stretching

Ethical Considerations

The Fundación Universitaria María Cano research committee approved the study on June 20th, 2017, as recorded in act #013004035-2017-31. The approval was given after following the guidelines of Resolution 008430, which classifies the study as having a "minimal risk" rank, in accordance with Article 11 (Minsalud, 1993) and the Declaration of Helsinki (World Medical Association, 2013). Before the study, the researchers provided the parents of the children with an informed consent form that outlined the study's objectives and risks, which was signed by the parents. The parents signed an authorization to publish their son's photograph in the paper.

Statistical Analysis

For this part of the study, an analysis of variance of repeated measures ANOVA (pre and post-test) was applied; the researchers contemplated group type (experimental and control) inter-subject factor since it is differentiated and helpful for the analysis. Compliance with assumptions was verified through the Levene and Shapiro–Wilk tests. In the presence of significant global differences, post hoc tests with Tukey's HSD correction were used to identify specific differences between pairs of groups. The analysis was applied considering the typical score that the sample obtained on such a scale. The calculation of the Reliable Change Index (RCI), according to what was noted in Jacobson and Truax (1991) is

$$RC = \frac{x_2 - x_1}{S_{diff}}$$

where x_2 is a score in the pretest and x_1 the score corresponding to the same subject in the pretest, S_{diff} is the standard error of the difference between the two scores. This measure can be expressed as a function of the standard deviation of the pretest for the control group s_1 and the Pearson product-moment correlation between the two r_{xx} measurements in the following way:

Table 3 Characteristics of the pre-intervention groups

	Total	Experimental Group	Control Group	Comparison of groups	
	N = 20	N = 10	N = 10	*F*	*p*
Age (SD)	5.8 (1.47)	5.8 (1.39)	5.8 (1.61)	0.56	1.000
Genre (f/m)	3/20	2/8	1/9	0.53*	0.556
Weight kg (SD)	25.17 (6.29)	25.92 (6.62)	24.43 (6.19)	0.61	0.610
Size Mt (SD)	1.197 (0.13)	1.216 (0.09)	1.182 (0.16)	0.28	0.594
Socioeconomic status (range)	Low	Low	Low	0.20*	0.137
Schooled	65%	70%	60%	0.64*	0.660
Previous-gross motor skills	40.75 (6.75)	39.4 (7.50)	42.1 (5.90)	0.94	0.385

Independent sample t-tests were performed to calculate the differences between both groups. The * chi-square test was used to calculate the differences between categorical variables. Fisher's exact tests were used for observations with an expected value < 5, p < .05

SD standard deviation

$$S_{diff} = \sqrt{2\left(S_E\right)^2}, \quad \text{with} \quad S_E = s_1\sqrt{1 - r_{xx}}.$$

The calculation being made as follows:

$$S_E = 5.915\sqrt{1 - 0.531} = 4.050$$

$$S_{diff} = \sqrt{2(4,050)^2} = 5,728$$

Results

The children were randomly assigned to the experimental or treatment as-usual group based on their age to ensure that the experimental and control groups were comparable. Each group consisted of 10 children, 90% male in the control group and 80% male in the experimental group. Both groups' mean age was 5.8 years, with standard deviations of 1.61 and 1.39 years, respectively. Most participants belonged to the low or medium–low socioeconomic strata; regarding education, 65% were in school (see Table 3).

The final group configuration was fairly equal, with no statistically significant differences between the groups in terms of their gender composition 22(1) = 0.40 $p = 0.528$, their age $t(18) = 0{,}00$ $p = 1.00$, average weight $t(18) = 0.52$ $p = 0.610$, height t(17) = 0.54 $p = 0.594$, socioeconomic stratum 22(2) = 3,31 $p = 0.191$, or the schooling level 22(1) = 0.22 $p = 0.639$.

Furthermore, the study used an analysis of variance of repeated measures (pre and post-test) differentiated by the type of group (experimental and control); it was applied to examine the effect of the intervention. Verification of compliance with the assumptions required for this test showed that normality and homoscedasticity were satisfied. According to the Shapiro–Wilk tests, neither of the two measures differed significantly from the standard curve ($p = 0.811$ and $p = 0.899$, respectively) and, according to the results of the Levene test, both measures comply with the assumption of homogeneity of variances ($p = 0.559$ and $p = 0.757$ respectively).

The descriptive results showed that the experimental group presents a mean in the pre-test (with standard deviation in parentheses) of 39.40 (5.44), while, in the post-test, the means of this group increased to 50.60 (7.56). Additionally, the control group showed a mean in the pre-test of 42.10 (5.92), while 42.90 (6.32) for the post-test (see Fig. 3).

The results of the repeated measures ANOVA showed that there were statistically significant global differences between the pre and post-test of the experimental and control groups, with a large effect size $F(1, 18) = 32.75$ $p < 0.001$ $\omega^2 = 0.15$. Specifically, with Tukey's correction, the examination of the post hoc tests indicated substantial differences between the means of the experimental group in the pre-test and the means of the same group in the post-test $t = 8.72$ $p < 0.001$. However, it did not reach the conventionally accepted levels of significance ($p < 0.05$); the difference between the two

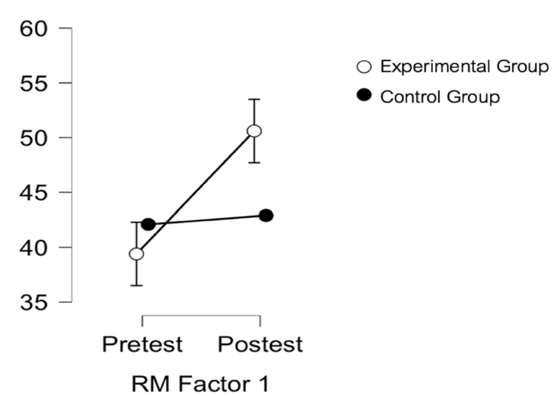

Fig. 3 Descriptive plots

groups in the post-test was very close to the same t = 2.71 $p = 0.058$.

Given this information, it is considered that the experimental group showed, in a greater proportion, reliable and significant changes compared to those of the control group.

Discussion

The main purpose of this study was to determine the effects of a physical exercise program on gross motor skills in children with ASD. For this purpose, a physical exercise program was designed and applied to 10 children randomly assigned to an experimental group.

Previous studies have shown that working with physical exercise programs such as walking, coordination, and strength exercises can be an alternative treatment for the acquisition of motor skills in children with ASD (Dong et al., 2021; Fessia et al., 2018; Sowa & Meulenbroek, 2012; Toscano et al., 2018).

The results showed good locomotor skills such as running, avoiding obstacles, and kicking the ball. As reported by Healy et al. (2018) in their meta-analysis on the effects of physical activity in young people with ASD, a moderate or significant impact on the development of manipulative skills, locomotor skills, skill-related physical fitness, functioning, strength, and muscular endurance, were found. Likewise, Dong et al. (2021) report significant locomotor skills such as ball manipulation activities. The participants with ASD showed a continuous improvement in their locomotor skills immediately after undergoing a motor program designed specifically to enhance their fundamental motor skills. However, no improvement was observed in their ball manipulation skills. This improvement was observed two months after the program was completed.

According to the study conducted by Kruger et al. (2019), a positive correlation was observed between high scores in motor skills in children with ASD and higher participation in physical education classes. The results indicated the importance of creating physical activity programs that improve the motor skills of this population is of prior importance in this research domain.

Among the systematic reviews of this kind of study, Busti Ceccarelli et al. (2020) analyzed ten studies carried out on autistic children between the ages of 3–12 years old that sought to know the effect of interventions to improve motor development. The results displayed that 70% of the studies evaluated interventions focused on fundamental movement skills (FMS), including strengthening locomotor and object control skills and integrated activities. The following are examples, primarily developed in schools or rehabilitation centers: "balance, run, roll underhand, gallop, jump, throw underhand, jump, dribble and bounce, throw over the hand, catch, jump, kick and hit" (Busti Ceccarelli et al. (2020)). After the interventions, all studies demonstrated potentially significant improvements in autistic children's motor skills.

Rafie et al. (2015) found that a ten-week group physical exercise program had positive effects on motor skills such as strength, balance, coordination of upper extremities, speed of upper extremities, dexterity, and visuomotor control in children with ASD. The findings suggested that these interventions should be started at an early age, particularly during early childhood, as this is a crucial and delicate period in the development and acquisition of motor skills, a recommendation supported by previous studies (Bremer et al., 2015; Bremer & Lloyd, 2016; Ferreira et al., 2018; Abdel Karim & Mohammed, 2015; Ketcheson et al., 2017, 2018, 2021; Najafabadi et al., 2018).

Studies have reported that exercise or physical activity is beneficial (Pan et al., 2017), not only for health reasons, but also for behavior and adaptation in the classroom, and positively influences communication, behavior, and social skills of children with ASD (Colombo-Dougovito & Block, 2019; Ketcheson et al., 2017; Lang et al., 2010; Lee et al., 2020; Zhao & Chen, 2018).

Similarly, Fessia et al. (2018) aimed to identify the strategies used in the development of the planned and scientifically documented physical activity, as well as the results achieved in these interventions in children with ASD; the researcher concludes that the programmed and correctly directed physical exercise allows developing motor skills and generating positive psychological contexts and behavioral changes.

In accordance with these findings, the current study saw changes in behavior among most of the children, such as the improved ability to follow instructions, increased social interaction with peers, and better response to verbal cues in the exercise setting. These behavioral changes, although not the main objective of the study, helped the children adapt to their surroundings.

Regarding the design of the exercise program applied to the experimental group, the circuits facilitated the acquisition of gross motor skills such as running, kicking the ball, jumping with both feet together, jumping moving both feet, going up and down two or more steps, alternating feet and performing some motor integration activity. In addition to that, the children demonstrated improvement in coordination, postural control, and balance. These results align with the findings of Gómez et al. (2008), who reported that circuit-based programs were effective in enhancing basic motor skills, general dynamic coordination, gait, running, jumping, and turning. Similarly, Šišková et al. (2020) found significant improvements in gross motor skills for both locomotion and object control in children with ASD through a 12-exercise motor program, including activities such as running, galloping, jumping, moving, throwing, and kicking the ball.

Regarding the intervention, the current study showed that applying exercises for eight weeks, 24 sessions of 60 min, three times a week, positively affected the acquisition of gross motor skills in children with ASD. Contrary to other studies that have established around eight weeks, 16 sessions of 30 min are distributed in 8 weeks, as reported by Šišková et al. (2020). Other studies demonstrated improvements in programs that spanned 12 weeks and 36 60-min sessions over 12 weeks (Arslan et al., 2020). For their part, Hassani et al. (2020) evaluated two physical activity programs of 16 sessions of 1 h in children with ASD aged 8–11 years. Both programs improved the children's gross motor skills in the experimental group compared to the control group.

Finally, these results provide empirical evidence on the effects of physical exercise on gross motor skills in children with ASD at an early age. These results align with the findings of Wainer et al. (2021) who emphasized the significance of specially designed physical activity programs for children with ASD, as they can have a lasting impact on their functioning (Šišková et al., 2020).

Limitations

A limitation of this study was the small sample size and the lack of follow-up, aspects that should be considered for future studies.

Author Contributions All authors contributed to the study's conception and design. Material preparation and data collection were performed by PRLC, DPMS, HPGC, LCGM, PASV, ERG, CR-C and statistical analysis was performed by CH-M. The first draft of the manuscript was written by PRLC, DPMS, ERG, CR-C, CH-M.

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Materials Availability The data can be consulted to the corresponding author via email at piedadrociolermacastano@fumc.edu.co.

Declarations

Conflict of Interest The authors state that they do not present any conflict of interest. The intervention was applied by the authors Piedad Rocio Lerma Castaño, Diana Paola Montealegre Suárez, and three students/research assistants from the physiotherapy program trained for its application.

Ethics Approval Approval was obtained from the ethics committee (minute 01 of June 20, 2017) and the research committee (assigned code # 013004035-2017-31) of la Fundación Universitaria María Cano. This approval supports that the procedures used in this study adhere to the postulates of the Helsinki declaration (World Medical Association, 2013). The committee observed the guidelines of resolution 008430 to attribute a "minimal risk" rank, as expressed in article 11 (Minsalud, 1993).

Consent The researchers prepared an informed consent form that included the objectives and risks of the study; it was signed by the parents of the children who agreed to participate.

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