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Effects of a physical exercise program in children with Autism Spectrum Disorder

Efeitos de um programa de exercício físico em crianças com Transtorno do Espectro Autista

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ABSTRACT

Objective: The study investigate study was to investigate the effects of a physical exercise program on the motor skills and physical activity levels of children with Autism Spectrum Disorder (ASD). Methods: Forty-nine children, aged 8 to 10 years, were randomly assigned to an exercise group (EG; n = 29) and a control group (CG; n = 20). The EG participated in a 16-week program, with three weekly sessions of 50 minutes each, consisting of both aerobic and strength exercises. Motor skills were measured by the Test of Gross Motor Development-2. Physical activity was assessed by accelerometry before the intervention, after 8 weeks, and after 16 weeks. Data analysis was conducted using Generalized Estimating Equations and Bonferroni post-hoc tests (α = 0.05). Results: 39 children completed the intervention. The results showed that the EG had higher scores related to motor skills compared to the CG after the intervention. Additionally, significant improvements in motor skills were observed in the EG from week 0 to week 8 and from week 8 to week 16, with no changes over time in the CG. The CG reduced physical activity levels from week 0 to week 8, and the EG remained stable. Conclusion: Children with ASD benefited from the physical exercise program, showing improvements in motor skills and maintenance of physical activity levels. Exercise programs should be used to promote inclusion in physical exercise promotion, mitigating disparities in access to physical activity and its associated benefits.

Keywords: Autism Spectrum Disorder; Test of Gross Motor Development-2; Accelerometry; Circuit-based exercise; Equity; Inclusion.

RESUMO

Objetivo: O estudo investigou os efeitos de um programa de exercícios físicos nas habilidades motoras e nos níveis de atividade física de crianças com Transtorno do Espectro Autista (TEA). Métodos: Quarenta e nove crianças, com idades entre 8 e 10 anos, foram aleatoriamente distribuídas em um grupo de exercícios (GE; n = 29) e um grupo controle (GC; n = 20). O GE participou de um programa de 16 semanas, com três sessões semanais de 50 minutos, incluindo exercícios aeróbicos e de força. As habilidades motoras foram avaliadas pelo Teste de Desenvolvimento Motor Grosso-2, e a atividade física por acelerometria, antes da intervenção, após 8 e 16 semanas. Os dados foram analisados por Equações de Estimativa Generalizadas e testes post-hoc de Bonferroni (α = 0,05). Resultados: Completaram a intervenção 39 crianças. Os resultados mostraram que o GE obteve escores mais altos em relação às habilidades motoras em comparação com o GC após a intervenção. Além disso, melhorias significativas nas habilidades motoras foram observadas no GE da semana 0 para a semana 8 e da semana 8 para a semana 16, sem alterações ao longo do tempo no GC. O GC apresentou redução nos níveis de atividade física da semana 0 para a semana 8, enquanto o GE manteve-se ativo. Conclusão: Crianças com TEA se beneficiaram do programa de exercícios físicos, apresentando melhorias nas habilidades motoras e manutenção dos níveis de atividade física. Programas de exercícios devem ser utilizados para promover a inclusão, reduzindo disparidades no acesso à atividade física e seus benefícios associados.

Palavras-chave: *Transtorno do Espectro Autista; Test of Gross Motor Development-2; Acelerometria; Exercício baseado em circuito; Equidade; Inclusão.*

Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by difficulties in communication, social interaction, and the presence of restrictive and repetitive behaviors[1]. Children with ASD often exhibit deficits in basic motor skills, such as gross and fine motor coordination, postural control, and balance[2]. These impairments can affect the performance of daily living activities, such as personal hygiene, eating, and dressing, as well as limit their participation in play and physical activities[3].

Physical exercise for children with ASD has been identified as a key intervention for improving motor coordination[4,5]. Structured physical activity programs

have demonstrated moderate to large effects on the development of manipulative and locomotor skills, physical fitness, and social functions[6]. Previous studies have demonstrated positive effects on the motor skills of children with ASD following programs involving sports and recreational physical exercises[4,7-9].

Studies indicate that most youth with ASD do not meet the minimum recommendations for moderate to vigorous physical activity (MVPA) per week[10-12]. Additionally, it has been found that gender, family income, and family structure are associated with physical activity scores. Furthermore, lack of opportunity and financial burden are highlighted as the main barriers to engaging in physical activity[12]. Despite the benefits reported in intervention studies with children with ASD, these studies have generally had small sample sizes[5,9,13] and are scarce in the Brazilian context. Bhat[14], in a study with 13887 children with ASD aged 5 to 15 years, from the United States of America, described that 87% of the sample had motor impairments. Similarly, as supported by the literature, children with ASD engage less and for shorter durations in MVPA[15]. Given the challenges, it is crucial to explore inclusive physical exercise interventions for people with ASD.

Despite the well-documented benefits of physical exercise for children with ASD internationally, there is still a lack of national studies on physical exercise interventions in children with ASD, especially those focusing on motor skills and physical activity levels. The present study aimed to investigate the effects of a 16-week physical exercise program on motor skills and physical activity levels in children with ASD aged 8 to 10 years.

Methods

Experimental design

This study is characterized as a randomized controlled trial, which assessed the effects of a 16-week combined physical exercise program, conducted three times a week, compared to a control group of children with ASD. The control group was instructed not to modify their physical activity habits during the study period. Motor skills and physical activity levels were measured at the start of the intervention, after eight weeks, and after 16 weeks of the physical exercise program. The study was carried out in 2019 at the conducted between at the School of Physical Education and Physiotherapy of the Federal University of Pelotas (Brazil).

Participants

The sample was intentionally selected in a non-probabilistic manner, aiming to include as many children as possible. A total of fifty-four children with ASD, aged 8 to 10 years, were invited to participate in the study, with five declining, resulting in a final sample of forty-nine children. All participants were attending one of the institutions that support children with ASD in Pelotas, Brazil. The invitation was also extended through media resources, including city websites, television, and radio.

A total of 49 children were included in the study. Ten children were unable to commit to the exercise protocol and were therefore allocated to the CG. The remaining 39 children were distributed between the exercise group (EG) and the control group (CG) based on age, gender, and severity of ASD. To account for the possibility of higher dropout rates in the EG, ten additional children were allocated to this group. As a result, the participants were divided into two groups: EG: n = 29 and CG: n = 20.

Ethics statement

The study was conducted following all ethical principles and was submitted and approved by the Research Ethics Committee of the School of Physical Education and Physiotherapy, Federal University of Pelotas (protocol no. 70687417.3.0000.5313). The Informed Consent Form was signed by the parents or legal guardians of the participating children. Due to the participants' characteristics with ASD, the signing of the Informed Assent Form was not required, and this procedure was duly justified and approved by the Ethics Committee.

Assessments

Motor skills and physical activity levels were measured at three distinct time points: 1) before the intervention (week 0); 2) before the 24th session (week 8); and 3) before the 48th session (week 16). At each of these times, participants from both groups (EG and CG) completed the Test of Gross Motor Development-2 (TGMD-2) and used an accelerometer for seven consecutive days. Parents and guardians of the children completed instruments related to the determination of ASD severity and lifestyle for sample characterization, while the tests were conducted at baseline.

Autism Spectrum Disorder support level

The support level of ASD for all participants was mea-

sured using the Childhood Autism Rating Scale[16]. This instrument, comprising a 15-item scale, evaluates impairments in social interaction, communication, and repetitive behaviors. Fourteen items assess general behavior across various domains, including personal relationships, imitation, emotional response, use of the body, use of objects, responses to changes, visual responses, auditory responses, responses to taste, smell, and touch, fear and anxiety, verbal communication, non-verbal communication, activity level, and the consistency of intellectual responses. The final item provides an overall impression based on observation of the child.

Each item is rated on a scale from 1 (within normal limits) to 4 (severe symptoms). After assessing the child and reviewing the parents' responses, the researcher rates each item on a 7-point scale with values ranging from 1 to 4, including intermediate values (1-1.5, 2-2.5, 3-3.5, 4). The total score ranges from 15 to 60, allowing for classification of ASD severity as follows: a) < 30 points: no ASD; b) 30 to 36 points: mild to moderate symptoms; and c) > 37 points: severe symptoms[17].

Motor skills

The TGMD-2 was used to assess gross motor development in locomotion and object control skills. The TGMD-2, which has been utilized in research with children with ASD[18], consists of 12 items—six related to locomotion skills (running, galloping, hopping, jumping on one foot, jumping with both feet, lateral running, and sliding) and six related to object control skills (catching, bouncing, receiving, kicking, overhead throwing, and rolling a ball). The TGMD-2 allows for separate evaluations of each item (locomotion and object control).

The test protocol suggests using a video camera to analyze motor performance after the test is administered. Each sub-item has different performance criteria based on video analysis. The child receives 1 point if they meet the criterion correctly and zero if they do not. The points obtained in each sub-item are immediately summed to generate raw scores. The raw score ranges from zero to 48 for locomotion skills and from zero to 48 for object control skills. All tests were analyzed by two assessors, and in case of disagreement, a third assessor was consulted to make the final decision.

Physical activity levels

Physical activity levels were objectively measured using the Actigraph GT3X accelerometer. This accelerometer measures 4.6 cm × 3.3 cm × 1.5 cm and weighs 19 grams. It records acceleration, energy expenditure, physical activity intensity, and body position. All children were asked to wear the device on their right hip secured with elastic straps for seven consecutive days at each assessment point (week 0, week 8, and week 16) and during classes to measure their intensity. Additionally, parents or guardians were given a diary to record periods when the accelerometer was not used.

After collecting the accelerometer data, the data were analyzed using the manufacturer's software. The data recording frequency was 60 Hz. A valid day for analysis required at least 480 minutes of recorded data[19]. Non-use was validated by 60 minutes of consecutive zeros, with a peak tolerance of 2 minutes to determine if the device was likely removed. Moreover, 60 minutes of zero data were interpreted as non-use periods. Physical activity was collected continuously in minutes but later categorized dichotomously (<300 min/week – insufficiently active; ≥300 min/week – active)[20]. Physical activity levels were assessed based on time spent in sedentary, light, moderate, vigorous, and very vigorous activities, as well as by counts per minute (cpm). The cut-off points proposed by Evenson et al.[21] were used to categorize activities into different intensities: light (101-2295 cpm), moderate (2296-4011 cpm), and vigorous (4012-∞ cpm).

Physical exercise program

The physical exercise program lasted 16 weeks, with a frequency of three 50-minute sessions per week. The classes were taught by four physical education teachers with prior experience working with the studied population. The number of students per class ranged from four to five children. Each session was composed of four parts: 1)Initial Circle: Upon entering the room, students were positioned in a circle for an explanation of the class by the instructors; 2)Warm-up: The warm-up involved games aimed at promoting social interaction and stimulating contact between peers (e.g., tag, music activities, playful exercises, among others); 3) Main Part: Aerobic Circuit - This included four aerobic activities (e.g., agility ladder, zig-zag cones, step jumping, among others) that needed to be repeated around four to five times; Strength Circuit- Exercises (e.g., squats, push-ups, TRX suspension training rows, medicine ball throws, planks, among others) targeting the lower limbs, upper limbs, trunk, and abdomen,

or multi-joint exercises; 4) Final Circle: The students were positioned again in a circle and a short stretching session was performed with breathing exercises and a discussion about how the class had been. This class structure was used throughout the program, as the importance of routine during classes was recognized due to the characteristics of ASD, to promote more effective adaptation. The materials used were: balls of different sizes and 2 kg medicine balls, hoops, agility ladders, steps, large and small cones, TRX suspension bands, benches, and ropes of different sizes.

Statistical analysis

Results were presented as mean ± standard deviation and frequencies. The Chi-Square test was used to compare the variables between groups at the beginning of the intervention. Generalized Estimating Equations and Bonferroni post-hoc tests were employed to compare between time points (week 0, week 8, and week 16) and between groups (EG and CG). The effect size (Cohen's d) was calculated from the mean values between EG and CG at weeks 8 and 16 and classified as small (between 0.2 and 0.5), moderate (between 0.5 and 0.8), or large (0.8 or more)[22]. To analyze the intensity of the EG classes across time points (class 3, class 24, and class 42), repeated measures ANOVA was used after testing for data normality with the Shapiro-Wilk test. Analyses were conducted using SPSS 20.0 software, and the significance level was set at $\alpha = 0.05$.

Results

Participants

The flow of participants through the study is presented in Figure 1. Of the 54 children who were contacted for participation, 49 were randomized (EG: n = 29; CG: n = 20) and 39 (EG: n = 19; CG: n = 20) completed the intervention and were included in the analysis. Ten participants dropped out during the intervention period due to problems not related to the study. In addition, it was not possible to obtain the physical activity data of six participants (1 from EG and 5 from CG), because the children did not accept the use of the accelerometer. Baseline characterization of participants is presented in Table 1.

Most of the children were male, 10 years old, and diagnosed with ASD by the age of three. Three children (7.8%) had siblings with disabilities: one with ASD, one with schizophrenia, and one with an intellectual disability. Eleven children (28.2%) had some health issue, including five with bronchitis (12.8%), three with rhinitis (7.8%), two with sinusitis (5.1%), and one with epilepsy (2.0%). Among the 32 children who were taking medication (82.1%), 21 were on more than one medication (53.8%). Most were using antidepressants combined with anxiolytics. The most frequently mentioned medication was risperidone (51.3%).

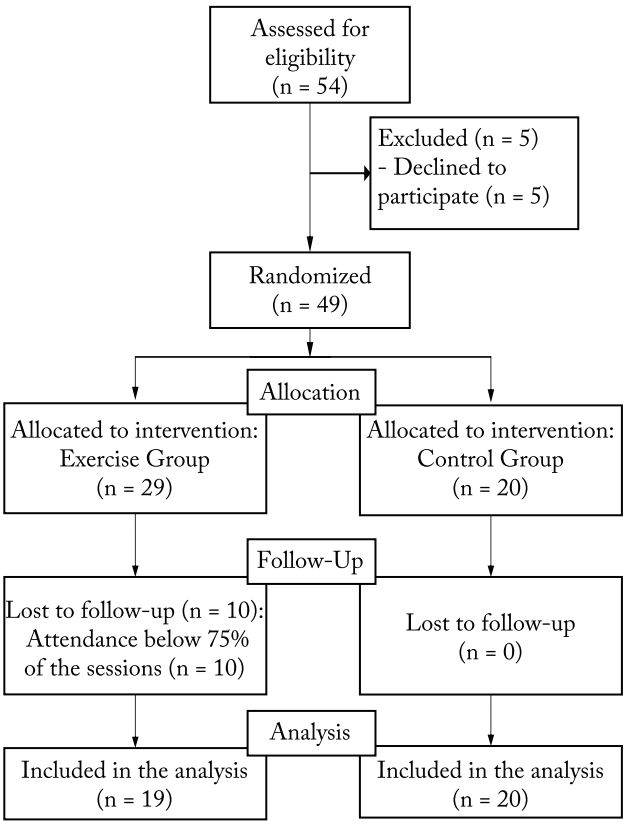

Figure 1 – Participants' flowchart

The results related to motor skills are presented in Table 2. A significant interaction was observed between group vs. time for variables related to locomotion skills ($p < 0.001$), object control ($p < 0.001$), and total TGMD-2 score ($p < 0.001$). The Bonferroni post-hoc test indicated that scores obtained by EG and CG were similar at week 0 (locomotion: $p = 0.391$; object control: $p = 0.474$; total score: $p = 0.407$), as well as at week 8 (locomotion: $p = 0.261$; object control: $p = 0.158$; total score: $p = 0.202$). At week 16, scores obtained by EG were higher compared to CG (locomotion: $p = 0.042$; object control: $p = 0.017$; total score: $p = 0.023$). Additionally, for EG, a significant improvement was observed in locomotion skills, object control, and the total TGMD-2 score from week 0 to week 8 ($p < 0.001$) and from week 8 to week 16 ($p < 0.001$). No changes were observed between time points for the CG.

The effect size analysis between the EG and CG results in the week 8 showed a small magnitude of effect for score total of TGMD-2 (0.40; 95% confidence interval [CI]: -0.23 to 1.04), locomotor (0.36; 95% CI: - 0.28 to 0.99) and object control (0.45; 95% CI: -0.19 to 1.09). Furthermore, the effect size analysis between the EG and CG data in the week 16 demonstrated a moderate magnitude of effect for score total of TGMD-2 (0.72; 95% CI: 0.07 to 1.37), locomotor (0.64; 95% CI: 0.00 to 1.28) and object control (0.76; 95% CI: 0.11 to 1.41).

Table 1 – Participants' characteristics at baseline

Variables	Exercise Group (n = 19)	Control Group (n = 20)	p value
	n (%)	n (%)	
Gender			0.908
Male	16 (84.2)	17 (85)	
Female	3 (15.8)	3 (15)	
Age (in complete years)			0.805
08 years	9 (47.4)	8 (40)	
09 years	4 (21.1)	6 (30)	
10 years	6 (31.6)	6 (30)	
Presence of disease			0.962
Yes	5 (26.3)	6 (30)	
Medication use			0.063
Yes	17 (89.5)	15 (75)	
No	2 (10.5)	5 (25)	
Doctor-reported ASD level			0.692
Level one	9 (47.4)	12 (60)	
Level two	8 (42.1)	5 (25)	
Level three	2 (10.5)	3 (15)	
Degree of ASD reported by Childhood Autism Rating Scale			0.423
Mild-Moderate	12 (63.2)	15 (75)	
Severe	7 (37.8)	5 (25)	
School attendance			0.477
Yes	19 (100)	19 (95)	
No	0 (0)	1 (5)	
Participation in physical education classes			0.130
Yes	12 (63.2)	18 (90)	
No	7 (37.8)	2 (10)	
Practice of physical activity during leisure time			0.165
Yes	5 (26.3)	10 (50)	
No	14 (73.7)	10 (50)	

The results related to physical activity level are presented in Figure 2. A significant interaction was observed between group vs. time (p = 0.003). The Bonferroni post-hoc test indicated that the groups had similar values at week 0 (p = 0.560) and week 8 (p = 0.148). However, at week 16, the CG had lower values compared to EG (p = 0.05). The CG reduced its physical activity level from week 0 to week 8 (p = 0.003) and from week 8 to week 16 (p < 0.001), with no difference between weeks 8 and 16 (p = 0.999). The physical activity level of EG remained unchanged. The effect size analysis between EG and CG results showed a small effect magnitude for physical activity level at week 8 (0.49; 95% CI: -0.21 to 1.18) and a moderate effect magnitude at week 16 (0.66; 95% CI: -0.04 to 1.37).

Figure 3 shows the time spent in MVPA during

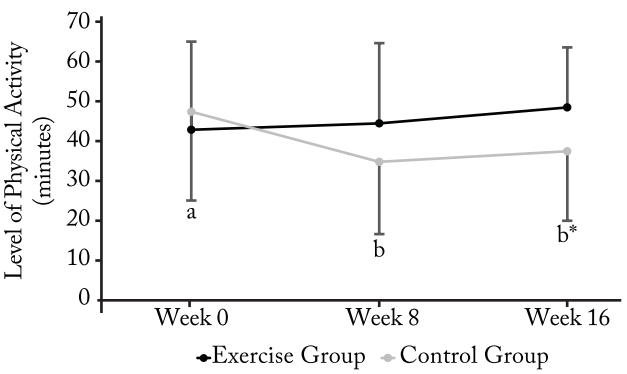

Figure 2 – Results of Level of Physical Activity before training and after 8 and 16 weeks of training: exercise group (n = 18) and control group (n = 15).
*indicates significant difference between groups. Different letters indicate a significant difference between moments for the control group.

Table 2 – Results of Test of Gross Motor Development-2 before training and after 8 and 16 weeks of training: exercise group and control group

Variables	Groups	Week 0	Week 8	Week 16			
		Mean ± SD	Mean ± SD	Mean ± SD	Group p	Time p	Interação p
Locomotor (score)	Exercise group	18 ± 15[a]	27 ± 17[b]	31 ± 15[c*]	0.536	<0.001	<0.001
	Control group	22 ± 13	22 ± 12	22 ± 13			
Object control (score)	Exercise group	13 ± 11[a]	22 ± 15[b]	26 ± 15[c*]	0.319	<0.001	<0.001
	Control group	15 ± 9	16 ± 8	16 ± 8			
Total (score)	Exercise group	31 ± 25[a]	49 ± 31[b]	57 ± 30[c*]	0.421	<0.001	<0.001
	Control group	37 ± 21	38 ± 19	38 ± 20			

* indicate significant difference between groups. Different letters indicate significant difference between moments for the Exercise group

the 3rd, 24th, and 42nd classes. The results indicated a difference in time spent in MVPA between the classes (p = 0.006). The Bonferroni post-hoc test revealed that the 42nd class had a significantly greater time spent in MVPA compared to the 3rd class (p = 0.016). The 24th class did not show a significant difference from the other two classes.

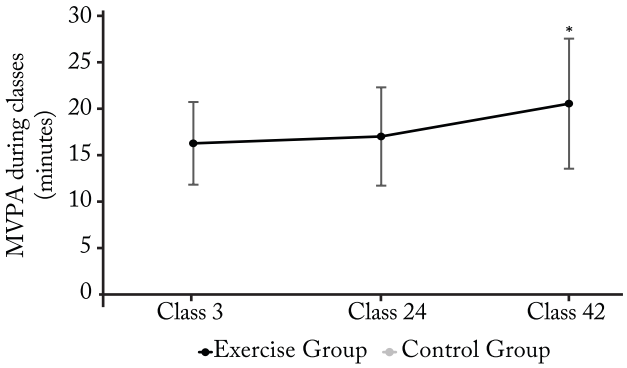

Figure 3 – Results of time in moderate to vigorous physical activities measured by the accelerometer during classes 3, 24, and 42 in the exercise group.
* indicates a significant difference between classes 3 and 42.

Discussion

The main findings of this study showed that 16 weeks of a combined physical exercise program positively impacted the locomotion and object control motor skills of children with ASD. However, although the program had effects on motor skills, this type of intervention did not change the participants' levels of physical activity.

The results showed increases of 72% in locomotion skills, 100% in object control skills, and 84% in the total TGMD-2 score. These findings are consistent with studies showing improvements in motor skills in children with ASD through exercise. Ketcheson et al.[5], in an eight-week study using recreational activities with 11 children with ASD aged 4 to 6 years, demonstrated increases of 94% in locomotion skills, 100% in object control skills, and 100% in the total score using the TGMD-2. In the study by Lourenço et al.[9], involving 17 children with ASD aged 4 to 10, where the exercise group participated in a weekly trampoline training session lasting 45 minutes, motor skills were assessed using the Bruininks-Oseretsky test battery, showing a 65% increase for the exercise group. Improvements in these motor skills are crucial for this population, as such characteristics have been reported as barriers to physical activity[23,24]. Many of these motor limitations are exacerbated by social misunderstandings of these children. Therefore, developing body awareness in different contexts during childhood, along with interacting with their environment, contributes to improving basic motor skills[25,26]. Consequently, children with ASD who exhibit better motor skills perform their daily activities with greater proficiency and independence[27], enhancing their social, physical, and cognitive development.

Despite some of the aforementioned studies presenting evidence of improvements in motor skills, a recent meta-analysis[28] indicated that children with ASD who participated in exercise programs did not show significantly better motor coordination compared to control children. One point of discussion was the variety in the type and implementation of practices (e.g., school physical education, Tai Chi, sports education, and table tennis). Therefore, it is highlighted that the characteristics of the exercise program in this study (structure, type of exercises, duration) may have contributed to positive outcomes in motor skills.

Physical activity at moderate-to-vigorous levels during the week showed a significant decrease in the CG. Numerous studies describe physical activity levels, noting that most children do not meet the World Health Organization's recommendation of 60 minutes of daily physical activity[6,12,29]. Pan et al.[8] conducted a study with youth aged 12 to 17 years with mild ASD, reporting that 13 of the 22 participants met the World Health Organization recommendations. In Stanish et al.[12], which included 30 adolescents aged 13 to 21 years, the average of MVPA was 29.1 minutes per day. Similarly, in the present study, only 20% (five from the EG and three from the CG) met the recommendations. Current research indicates that individuals with ASD benefit from physical activity, such as improvements in social skills[30], sleep quality[31], and reduced stereotypies[32]. However, research still shows that children and youth with ASD engage minimally in physical activity during leisure time[33] and, compared to their peers without disabilities, are 60% less likely to engage in regular physical activity and 74% less likely to participate in organized sports[34].

Despite the concerningly low levels of physical activity in children with ASD[35], the exercise program in this study was not able to improve participants' daily levels of MVPA, even with significant improvements in motor skills. This suggests that gains in motor skills alone were not sufficient to increase MVPA levels in children with ASD. However, it is important to note that the study lasted 16 weeks, raising the hypothe-

sis that such motor improvements may foster greater engagement in physical activity over the long term. Moreover, behavior change is known to be a complex process influenced by various factors beyond motor competence, such as motivation, social inclusion, environmental opportunities, and, especially in individuals with ASD, family support, which is essential to promoting meaningful and lasting change.

Regarding participation in the classes, a significant increase in the time spent in MVPA was observed from class three (16 minutes) to class 42 (21 minutes). This suggests that the increased participation of students over time contributed to the intensity of the classes, which may be related to the level of participation in them. This improvement can be explained by the significant enhancement in motor skills observed during the activities, as children with better skills and a higher sense of competence interact more efficiently, boosting their self-esteem and feeling more integrated into the group[27]. Zhao and Chen[30] observed in their intervention that a structured 12-week physical activity program, with two sessions per week, led to significant improvements in social interaction and communication for children with ASD.

However, this study presents some limitations, such as the use of a non-probabilistic sampling method, which may compromise the generalizability of the findings, and the absence of evaluator blinding. In addition, there was a loss of ten children from the intervention group. This dropout occurred because some participants had difficulty attending the proposed three weekly sessions or did not adapt well to the group-based methodology. Moreover, ten children were directly allocated to the CG, as their families had previously informed, prior to randomization, that they would not be willing to adhere to the required number of weekly sessions in the program. Since most studies in this field have small sample sizes, we decided to retain these children in the study. The absence of prospective registration of the clinical trial also represents an important limitation. Nevertheless, the study was conducted under the supervision of experienced researchers and in full compliance with ethical guidelines. All methodological details and data analyses were thoroughly reported to ensure transparency.

It is worth highlighting the use of validated assessment instruments, including the motor skills assessment and the accelerometry. Additionally, the observed improvements in locomotor and object control motor skills were achieved through a simple physical exercise program that required minimal equipment and was adapted to children with different levels of ASD support. This reinforces its applicability in different school and community settings, where resources are often limited.

Based on the results obtained, it can be concluded that a 16-week physical exercise program, consisting of three 50-minute sessions per week, is effective in improving motor skills and maintaining physical activity levels in children with ASD. A progressive increase in participation was also observed throughout the intervention, resulting in a gradual rise in the intensity of the classes. Given these findings, structured and periodized physical exercise programs prove to be an effective intervention for the motor development of children with ASD. Furthermore, the implementation of adapted programs can promote inclusion and engagement in physical activities, helping to reduce disparities in access and ensuring that vulnerable populations can benefit from the health advantages associated with regular physical activity. It is recommended that future research explore the long-term impact of these interventions, as well as strategies that integrate motivational aspects, family support, and environmental opportunities to promote sustainable behavioral changes.

Conflict of interest

The authors declare no conflict of interest.

Author's contributions

Krüger GR: Conceptualization; Methodology; Formal analysis; Investigation; Data curation; Supervision; Project administration; Visualization; Writing – original draft; Writing – review & editing; Approval of the final version. Müller WA: Methodology; Formal analysis; Visualization; Writing – original draft; Writing – review & editing; Approval of the final version. Gomes TVB: Visualization; Writing – review & editing; Approval of the final version. Seron BB: Methodology; Formal analysis; Visualization; Writing – review & editing; Approval of the final version.

Declaration regarding the use of artificial intelligence tools in the article writing process

The authors did not use artificial intelligence tools for preparation of the manuscript.

Availability of research data and other materials

After publication the data will be available on demand to authors.

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Reviewers' assessment

The reviews of this article were originally conducted in Portuguese. This version has been translated using ChatGPT and subsequently reviewed by the Chief Editors.

Reviewer A

Anonymous

Format

- Does the article comply with the manuscript preparation guidelines for submission to the Revista Brasileira de Atividade Física e Saúde?
  Partially
- Regarding formal aspects, is the manuscript well structured, containing the sections: introduction, methods, results, and discussion (with the conclusion as part of the discussion)?
  Yes
- Is the language appropriate? Is the text clear, precise, and objective?
  Yes
- Was any indication of plagiarism observed in the manuscript?
- Yes

Suggestions/comments:

- The article partially complies with the manuscript preparation guidelines for submission to the Revista Brasileira de Atividade Física e Saúde. It is necessary to review the number of references, especially references 9 and 13, and remove the DOI from the references.
- Regarding formal aspects, the manuscript is well structured, containing the sections introduction, methods, results, and discussion (with the conclusion as part of the discussion), highlighting important aspects in each section, which are entirely appropriate.
- The text is well written, employing scientific language with objectivity. No grammatical agreement errors or typographical errors were found.
- Regarding plagiarism detection, Justdone was used on the English version of the text, revealing a high level of plagiarism (86% average plagiarism; 34% with minor changes and 17% identical). The Portuguese-translated version also showed a high level of plagiarism (70% average plagiarism; 44% with minor changes and 13% identical).
- **Suggestion:** This must be corrected by rewriting the plagiarized text.

Abstract

- Are the abstract and abstract (Portuguese and English) appropriate (including: objective, participant information, variables studied, main results, and conclusion) and do they reflect the manuscript content?
  Partially

Suggestions/comments:

- Although the abstract contains the important aspects, it does not mention that the level of support for Autism Spectrum Disorder was measured using the Childhood Autism Rating Scale, as described in the Methods section.
- Another necessary correction concerns the number of children in the two groups. It states that 49 children were randomly allocated, with an exercise group (EG: n=29) and a control group (CG: n=20). However, the text indicates that 39 children (EG: n=19; CG: n=20) completed the intervention and were included in the analysis. Therefore, the abstract should report only the children who completed all study stages in both EG and CG.

Introduction

- Was the research problem clearly stated and delimited?
  Partially
- Is the research problem adequately contextualized in relation to existing knowledge, moving from general to specific?
  Partially
- Are the reasons justifying the study (including the authors' assumptions about the problem) well established?
  Partially
- Are the references used to support the presentation of the research problem current and relevant?
  Partially
- Was the objective clearly presented?
  Yes

Suggestions/comments:

- The research problem is partially stated and delimited, but not explicitly mentioned. However, the general objective clarifies the object investigated.
- Suggestion: Add a clear statement of the research

problem before the general objective.
- Include similar studies in the Introduction and compare their findings in the Discussion, especially regarding 16-week exercise effects on motor skills and physical activity levels in children with ASD aged 8–10 years. There is no mention in the Introduction of studies addressing physical activity levels.
- The justification needs strengthening based on similar previous studies.
- References are partially current and relevant (years ranging from 2004 to 2019).
- Suggestion: Include more recent studies (last 5 years).
- The general objective is clearly presented.

Methods
- Are the methodological procedures generally adequate?
  Yes
- Are they sufficiently detailed?
  Partially
- Was the participant selection/recruitment procedure adequate and clearly described?
  Partially
- Were instruments described, including psychometric qualities and operational definitions?
  Partially
- Is the data analysis plan adequate and well described?
  Yes
- Were inclusion/exclusion criteria described and appropriate?
- No
- Were ethical procedures clarified?
  Yes

Suggestions/comments:
- Methods are generally adequate and well described; however, the routine of the control group was not reported (e.g., whether they continued usual exercise).
- Clarify how 10 additional children were allocated to the exercise group due to anticipated dropout.
- Provide more details on the institution and ASD support levels.
- Include psychometric properties of instruments.
- Inclusion/exclusion criteria were not described. Clarify discrepancies in group numbers.
- Ethical procedures were described, including ethics approval and consent/assent forms.
- Suggestion**:** Explain how children with ASD (including level 3) understood and signed the assent form, and whether adaptations were made.

Results
- Is the use of tables/figures appropriate?
  Yes
- Are participant flow and losses described?
  Yes
- Are participant characteristics sufficient?
- No
-
- Are results adequately presented without repetition?
  Yes

Suggestions/comments:
- Tables and figures are appropriate (3 figures, 2 tables).
- 49 children randomized; 39 completed (EG:19; CG:20). Reasons for dropout were explained.
- Participant characteristics are partially described. Missing comments on ASD levels (medical and CARS), school attendance, PE participation, and leisure-time physical activity.
- Suggestion: Justify the use of CARS and clarify DSM-5/CID-11 considerations.

Discussion
- Are main findings presented?
  Yes
- Are limitations and strengths discussed?
  Partially
- Are results discussed considering limitations and existing knowledge?
  Yes
- Are potential contributions discussed?
- No

Suggestions/comments:
- Main findings clearly presented (motor skill improvements but no increase in physical activity levels).
- Limitations include dropout and lack of clinical trial registration. Strengths not clearly highlighted.
- Include more similar studies for comparison.
- Discuss potential contributions to scientific advancement and practical intervention.

Conclusion
- Is it appropriate and coherent?

Yes
- Is it original?
- No

Suggestions/comments:
- Conclusion aligns with objective and findings.
- Not considered original, as similar evidence exists. Reference Monteiro et al. (2022) noting differing results.

References
- Are they updated and sufficient?
  Partially
- Do they follow journal guidelines?
  Partially
- Are citations appropriate?
  Yes

Suggestions/comments:
- Include more recent studies.
- Reduce references from 34 to recommended 30.
- Adjust formatting (especially references 9 and 13).
- Remove DOIs.

Comments to the author
- The article addresses a highly relevant and current scientific topic, particularly for Physical Education. Corrections were suggested for resubmission to improve quality.

Final decision
- Reject

Reviewer B
Letícia Perticarrara Ferezin
University of São Paulo, Faculty of Medicine of Ribeirão Preto, Rio Preto, São Paulo, Brazil.

Format
- Does the article comply with submission guidelines?
  Yes
- Is it well structured?
  Yes
- Is the language adequate?
  Partially
- Was plagiarism observed?
  Yes

Suggestions/comments:
- Some English sections require grammatical and fluency revision by a fluent/native speaker.

Abstract
- Is it appropriate and reflective of the manuscript?
  Yes
- **Suggestion:**
- Restructure after manuscript revisions.

Introduction
- Research problem clearly stated?
  Partially
- Contextualized adequately?
  Yes
- Justification well established?
  Yes
- References current?
  Partially

Suggestions/comments:
- Well grounded but lengthy.
- Synthesize descriptive sections about ASD.
- Emphasize scientific gap more clearly.
- Some references are outdated or lack Brazilian context.

Methods
- Methodological procedures adequate and detailed?
  Yes
- Selection/recruitment adequate?
  Yes
- Instruments and psychometrics described?
  Yes
- Data analysis plan adequate?
  Yes
- Inclusion/exclusion criteria described?
  Yes
- Ethical procedures clarified?
- No

Suggestions/comments:
- Clarify randomization after excluding non-adherent participants.
- Include dropout reasons in flowchart and clarify intention-to-treat vs per-protocol analysis.
- Better justify accelerometer criteria.
- Add an “Ethical aspects” section with committee approval and CAAE number.

Results
- Use of tables/figures appropriate?
  Yes
- Participant flow adequately described?
  Partially

- Participant characteristics sufficient?
  Yes
- Results adequately presented?
  Yes
  Suggestions/comments:
- Only 20% reached recommended activity levels; this deserves deeper discussion.

Discussion

- Main findings presented?
  Yes
- Limitations and strengths discussed?
  Partially
- Results contextualized?
  Yes
- Potential contributions discussed?
  Partially
  Suggestions/comments:
- Expand discussion on null effect for physical activity levels.
- Discuss whether motor gains may improve future engagement.
- Highlight applicability in schools/community.
- Include sampling limitation (non-probabilistic), lack of trial registration, potential bias from losses, and lack of assessor blinding.

Conclusion

- Appropriate and coherent?
  Partially
- Original?
  Yes
  Suggestion:
- Expand practical implications and future research recommendations.

References

- Updated and sufficient?
  Partially
- Mostly original articles?
  Yes
- Follow journal guidelines?
  Partially
- Citations appropriate?
  Yes
  Suggestion:
- Add more recent references.

Comments to the author

- The study evaluates the effects of a combined (aerobic and strength) exercise program in children with ASD, focusing on motor skills and physical activity levels. Positive effects were observed in motor skills but not in overall physical activity levels.
  Strengths:
- Relevant topic with practical applicability.
- Well-structured and replicable intervention protocol.
- Objective physical activity assessment (accelerometry).
- Validated instrument for motor skills (TGMD-2).
- Well-structured exercise sessions respecting ASD characteristics.

Final decision

- Major revisions required