Randomized crossover trial of exergame or physical education sessions benefit subsequent inhibitory control in children with autism spectrum disorder

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Abstract

Background: Autism Spectrum Disorder (ASD) is characterized by persistent impairments in reciprocal social communication and social interaction and restricted and repetitive patterns of behavior, interest or activities; as well as three levels of support for each domain: level 1, requiring support; level 2, requiring substantial support; and level 3, requiring very substantial support.

Objective: This study investigated the acute effects of Exergames (EX) and Physical Education (PE) on inhibitory control in children with Autism Spectrum Disorder (ASD).

Methods: First, they underwent anthropometric assessment, the KTK and Raven's tests, and familiarization with the cognitive task. They were then given two 20-minute sessions in random order: 1) Physical education session 153.8 bpm (95% CI 139.4, 168.0); exergames session 129.0 bpm (95% CI 121.8, 135.6). To assess inhibitory control, after 5 minutes of recovery, all participants completed a Flanker Task version and responded to the stimulus located in the central target in the middle of four identical congruent (fish facing the same direction) or incongruent (opposite direction) flanker stimuli, for a total of 108 trials.

Results: The ANOVA indicated a difference in incongruent reaction time between the sessions, with a better result in the EX session 849 (95% CI 642, 1057) than in the PE session 938 (95% CI 684, 1191). These results indicate that just one 20-minute session of Exergames was effective in improving inhibitory control in children with ASD.

Conclusions: Thus, a short period of this session during school can benefit inhibitory control, improving the cognitive capacity of children with ASD and thus contributing to be. Clinical Trial: This study was registered in the Brazilian Registry of Clinical Trials - ReBEC under the number RBR-5r9xzbq.

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RANDOMIZED CROSSOVER TRIAL OF EXERGAME OR PHYSICAL EDUCATION SESSIONS BENEFIT SUBSEQUENT INHIBITORY CONTROL IN CHILDREN WITH AUTISM SPECTRUM DISORDER

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Abstract

This study investigated the acute effects of Exergames (EX) and Physical Education (PE) on inhibitory control in children with Autism Spectrum Disorder (ASD). Nine boys (8.6 ± 1.4 years old; 35.7 ± 14.4 kg; 1.38 ± 0.12 m; 18.0 ± 4.9 kg/m^2) took part in the study. First, they underwent anthropometric assessment, the KTK and Raven's tests, and familiarization with the cognitive task. They were then given two 20-minute sessions in random order: 1) Physical education session 153.8 bpm (95% CI 139.4, 168.0); exergames session 129.0 bpm (95% CI 121.8, 135.6). To assess inhibitory control, after 5 minutes of recovery, all participants completed a Flanker Task version and responded to the stimulus located in the central target in the middle of four identical congruent (fish facing the same direction) or incongruent (opposite direction) flanker stimuli, for a total of 108 trials. The ANOVA indicated a difference in incongruent reaction time between the sessions, with a better result in the EX session 849 (95% CI 642, 1057) than in the PE session 938 (95% CI 684, 1191). These results indicate that just one 20-minute session of Exergames was effective in improving inhibitory control in children with ASD. Thus, a short period of this session during school can benefit inhibitory control, improving the cognitive capacity of children with ASD and thus contributing to be. This study was registered in the Brazilian Registry of Clinical Trials - ReBEC under the number RBR-5r9xzbq.

Keywords: Physical Education. Executive Function. Autism Spectrum Disorder. Exergaming. Attention.

Introduction

Autism Spectrum Disorder (ASD) is characterized by significant challenges in reciprocal social communication and social interactions, as well as restricted and repetitive behavioral patterns[1,2]. These challenges in individuals with ASD are associated by pronounced impairments in executive functions, especially inhibitory control, which is linked to deficits in social communication[3] and repetitive behaviors[4]. Additionally, impairments in inhibitory control and working memory in children with ASD are associated with low school readiness[5]. Inhibitory control has been suggested to be crucial for academic performance, as it regulates attention, behavior, and thought[6], and manages emotions to overcome internal impulses or external stimuli, thus adapting to challenging contexts[7]. This understanding underscores the importance of investigating inhibitory processes in ASD and the variables that may influence their impact.

Studies have demonstrated the benefits of physical exercise on inhibitory control in neurotypical children[8] and with ASD[9]. For example, a study involving children with ASD conducted three 20-minute exercise sessions — circuit training, treadmill walking, and a sedentary control — and observed significant improvements in cerebral oxygenation and inhibitory control during the exercise sessions[9]. These acute exercise benefits can be attributed to the release of catecholamines and neurotrophic factors[10], as well as enhanced regulation of cerebral oxigenation, resulting in improved cognitive processing[9,11]. However, children often fail to meet movement recommendations[12,13], and more concerningly, children with ASD tend to engage less in school movement activities than their neurotypical peers[14]. According to the physical activity recommendation and the World Health Organization's campaign that "every move counts" as long as it is convenient, enjoyable, safe, accessible, and valued[15,16]. It is essential to explore alternative strategies that not only meet physical activity recommendations but also verify the potential positive impact of these activities on inhibitory control in children with ASD.

Engaging children in playful activities such as play can be an effective approach to promote physical activity and enhance inhibitory control during classroom time[17]. However, it remains unclear whether exercise sessions based on play produce the same effects on inhibitory control in children with ASD. Physical Education classes, part of the school curriculum in Brazil, are essential elements of child development, providing a means for children to explore feelings, emotions, and develop reasoning, imagination, and creativity through play and games[18,19]. However, children with ASD often face difficulties participating in symbolic play due to delays in behavioral skills such as communication and socialization, as well as learning barriers such as rigidity and repetitive behaviors[20]. These barriers can result in social isolation and reduce the opportunities to develop all

the skills that traditional Physical Education can offer along with their peers[21,22]. These challenges highlight the importance of adapting school Physical Education sessions to meet the behavioral needs of children with ASD, exploring other alternative practices that can provide the same benefits for executive control, particularly inhibitory control.

In this context, exergaming, which integrates physical exercises with interactive digital games, has emerged as an intervention with benefits on executive functions[23]. It has been suggested that a single 20-minute session of exergames, using platforms such as Dance Dance Revolution and Cybercycling, can promote significant improvements in executive function in young with ASD[24]. Additionally, a systematic review suggested that exergaming interventions also led to significant increases in physical fitness, executive function, and self-perception, as well as enhanced participation in moderate-to-vigorous physical activities[25]. These results indicate that exergaming could be a viable alternative to traditional physical activity programs for individuals with ASD. However, further research is needed to provide more robust evidence on the efficacy of the acute effects of exergame interventions for children with ASD, particularly in the school context as an alternative approach.

Taking into account the benefits linked to the use of exergames and physical exercise on children's cognition, this exploratory study used an Inhibitory Control test (Flanker's Task) to analyze the acute effect of three sessions lasting only 20 min (exergames, Physical Education class, and a sedentary control session) on the EFs of children with ASD.

Methods

Procedures

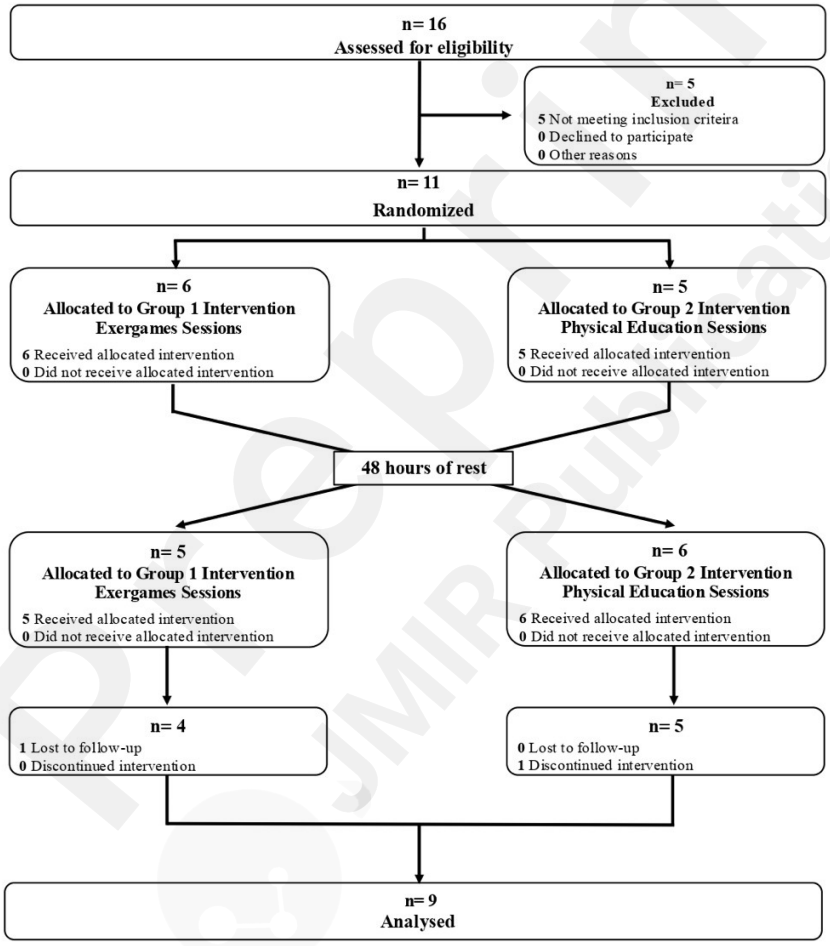
This prospective, randomized, crossover clinical study (RBR-5r9xzbq) was approved by the Brazilian Registry of Clinical Trials (ReBEC). The study followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines for randomized clinical trials (Supplement 1).

The allocation of participants to the experimental and control groups was carried out randomly, guaranteeing the minimization of bias and increasing the reliability of the results obtained. To ensure impartiality, randomization was carried out by a blinded researcher who was not involved in the data collection. The electronic list used for allocation was generated on the website https://www.graphpad.com/quickcalcs/randMenu/, guaranteeing a rigorous random selection process. This approach ensured that each participant had an equal chance of being assigned to any of the groups, reinforcing the internal and external validity of the study.

In a randomized controlled trial with a crossover design (Figure 1)[26,27], all children studied

underwent two different experimental conditions. The exercise protocol was previously tested in a pilot study and subsequently applied with an interval of 48 hours and included (1) an Exergame session and (2) a Physical Education session. After each session, a cognitive test was performed within 5 minutes after the interventions. The acute effects of exergames were compared with the acute effects of the PE class in school-aged children with ASD in the public school system of the Federal District. The sessions were controlled (drawn) by the researcher and applied to the children randomly.

Fig.1 Consort flow diagram for crossover trials



Source: Prepared by the author

Nine Brazilian schoolchildren, who were between 6 and 11 years old, male, and enrolled in a public elementary school in the Federal District, participated in the study. Inclusion criteria were children enrolled in school, diagnosed with ASD according to the Diagnostic and Statistical Manual of Mental Disorders – DSM-5[28], with no history of diseases including physical, pulmonary, and cardiac malformation. The exclusion criteria were non-verbal ASD, intellectual disability (IQ below 70), and age below 6 and above 11 years.

Before the children could participate, the parents or guardians signed a free and informed consent form. They were informed of the objectives and procedures and told the risks and benefits of participating in the study. They also provided their child's case history. The research was approved by the Ethics Committee on Human Research of the Catholic University of Brasília (CEP-UCB), opinion No. 5,448,930.

The evaluations and interventions were carried out on the premises of the Class 10 School of Taguatinga (EC10). Five meetings were necessary to carry out the study. The first meeting entailed anthropometric measurements and the battery of the Body Coordination Test for Children (Körperkoordinations Test Für Kinder – KTK). In the second meeting, Raven's Colored Progressive Matrices Test was applied. The third involved familiarization with Flanker's Task. In the last two meetings, the with Exergames and PE sessions were followed by the application of Flanker's Task. All tests were performed on the premises of EC10.

Instruments

Body Mass Index

Weight and height were measured by an electronic scale (Tech 05, China) and a fixed wall stadiometer (cm – Sanny ES 2040), respectively, following the procedures described by Heyward[29]. The Body Mass Index (BMI) was calculated considering the ratio between body mass in kilograms and height in meters raised to the second power (kg/m²). The calculations were performed according to the guidelines of the Centers for Disease Control and Prevention[30].

Heart Rate

Heart Rate (HR) was measured during physical exercise using a smartwatch (Galaxy Watch4 BT 40mm). HR was recorded at rest 0 and after 5, 10, 15, and 20 minutes of exercise, and the mean was calculated from all readings. Activity intensity was defined by the Maximum Heart Rate (HRmax), using the Tanaka formula (208 - 0.7*age)[29,31,32].

Body Coordination Test for Children

The motor skills of the participating students were assessed using the Body Coordination Test for Children (KTK - Körperkoordinationtest Für Kinder). The KTK tests are an instrument to evaluate motor skills that involve all aspects of body coordination. Balance, rhythm, strength, laterality, speed, and agility components were assessed in a battery of four tasks – Balancing, Jump on One Foot, Lateral Jump, and Lateral Transposition – all aimed at characterizing facets of total

body coordination and body mastery[33].

Raven's Colored Progressive Matrices test

The Raven's Colored Progressive Matrices test, a non-verbal intellectual evaluation, was used to assess intelligence. The test consists of 36 figures in three series of 12 items each (A, Ab, B), and the sum of these three items represents the overall score. Thus, item B was more difficult than Ab, and Ab was more difficult than A.

The test presents figures with a missing a part. Analyzing six possible alternatives, the child points to the only answer that completes the figure. Thus, one point was considered for each correct answer and zero for the wrong answers, for a total minimum score of zero and a maximum of 36 points.

In the first section, children needed to complete the missing part of a continuous pattern with the identical or sequential pattern, while the Ab and B parts involved analogies, permutation, pattern alteration, and logical relationships, with no time limit[34,35].

The raw score was calculated based on the sum of all correct items of the task. Then, the score was converted into a percentile corresponding to the child's age and the total points obtained. Converting the raw score into percentile and standard scores allowed the child's intelligence level to be interpreted.

Selective Attention Test (Flanker Task)

A modified version of the Eriksen Flanker task[36,37] was used to assess attentional inhibition. In this task, the stimuli were composed of visual representations of fish, and each illustration contained a target fish presented in the center, with the head facing to the right or left. The fish that should be the target of the child's attention was presented at the center of a sequence of five fish, and those positioned on the sides (flankers) were to be ignored. Children were instructed to indicate the direction of the target stimulus by pressing the keys (← for left-facing target fish stimulus and → for right-facing target fish stimulus). The task consisted of combinations of congruent assays, where the direction of the flanking fish corresponded with the target fish, and incongruent assays, where the direction of the flanking fish was opposite to that of the target fish.

The experiment was conducted in a room with ambient light and air conditioning, where the children were positioned in front of a microcomputer programmed to present the stimuli with the E-Prime v300 program (Psychological Software Tools Inc.).

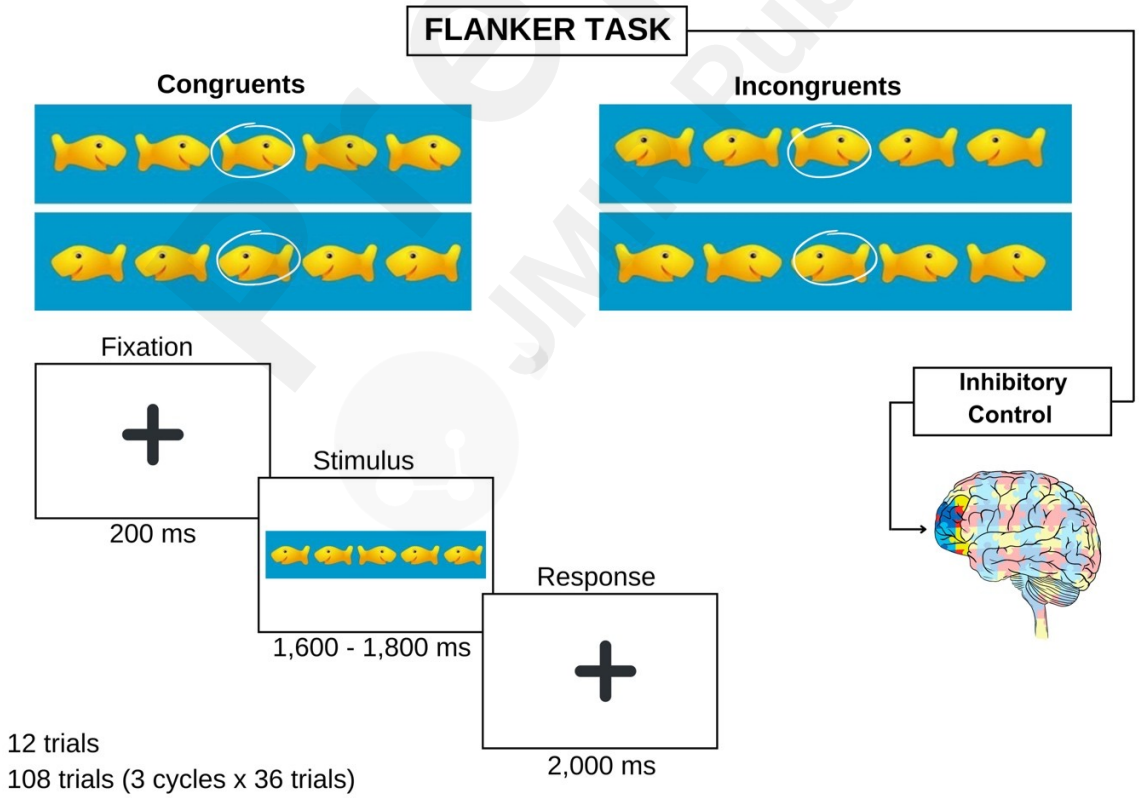
Before the test began, the examiner explained how the procedure worked. A familiarization

session was performed with 12 trials (3 trials of each type of congruence – congruent and incongruent right; congruent and incongruent left), followed by the application of the experimental task, which consisted of 108 test trials presented in three blocks (36 tests/block), with equiprobable distributions of congruent and incongruent trials, as well as the presentation of the target fish on the left and right in random order, with the types of trials being randomly mixed. The presentation was balanced so that all possible stimulus-flanker pairs occurred equally.

Each test began with the presentation of a central fixation point. Then, the stimuli of five fish, illustrated in yellow and 2.5 cm on a blue background was presented for 200 ms. For each test, the stimuli remained on the monitor until a response was made or for up to 2,000 ms. Test stimuli were presented at varying intervals of 1,600, 1,700, or 1,800 ms. The research was carried out based on important studies that used Flanker to analyze inhibitory control in children with ASD[38–40].

For each trial, children were instructed to indicate the orientation of a central target fish stimulus by pressing a keyboard button (left versus right) as quickly and accurately as possible (Figure 2).

Fig.2 Modified Flanker Test



Source: Prepared by the author

Sessions: Exergames – Just Dance® 2022, Physical Education - Active Play and Sedentary Control

The digital dance game Just Dance® 2022 recognizes body movements through devices, such as Kinect (Xbox®), and includes different colors and movements with varying levels of difficulty. These interactive dance games are effective tools for resembles moderate to high-intensity interval exercise, in addition to reducing BMI and increasing HR[41].

Just Dance® fosters movement that resembles moderate to high-intensity interval exercises. The players receive a score according to their movements, i.e., the more similar their movement is to that shown on the television (TV), the better the player is and the higher the score they receive. This stimulates the release of serotonin by the brain and the feeling of pleasure provided by it, not only due to the practice of physical activity but also by the achievements viewed on the TV screen.

The Just Dance exercise session was conducted in an air-conditioned classroom at the school. An Xbox One® console with a Kinect sensor, a SAMSUNG TV model UN32J4290, and the Just Dance® 2022 game were used for this intervention. The TV and Kinect sensor were positioned at 0.8 m from the ground, and the player remained at a minimum distance of 1.8 m from the TV. The Xbox One® console was held horizontally.

The Just Dance® intervention consisted of five songs with a total time of 20 minutes and 50 seconds with an interval of 15 seconds between each song, totaling 22 minutes and 05 seconds at the end of the intervention. Songs were selected according to the difficulty level of the choreography (easy to difficult level) (Supplement 2).

PE classes in the school environment are very important for children to learn about and experience body movements, letting each participant become aware of their body and social inclusion and simultaneously expand their motor skills[42] (Supplement 3).

In addition, it provides children with ASD a great opportunity to develop globally because PE combines all dimensions of a person: intellectual, physical, social, and cultural, by offering a series of possibilities to enrich the experience of these children[43].

The exercise session with the active games was held on the school's multi-sport court and consisted of three games: statue of the body parts, save yourself with a hug, or odd pike and hula hoop dance. A JBL Flip 4 Bluetooth sound box with 20W and 15 arcs (hoop) was used to carry out these activities.

The intervention lasted 20 minutes, and the contents were done according to the Movement Curriculum of the Federal District – Elementary School Initial Years – Final Years[42]. The class was taught with activities that required different perceptual-motor skills (coordination, laterality, balance, and temporal space organization), play and games with simple rules; social and school life; respect for diversity; cooperation and solidarity.

In the sedentary control session, the children colored pictures of superheroes for 20 minutes. They then waited 5 minutes for the Flanker Task.

In both the Just Dance® and active play sessions, the children participated with their classmates. At the end of the activities, they were taken to a classroom where the Flanker Task cognitive test was applied.

Data Analysis

The normality of the Reaction Time and Accuracy scores, both congruent and incongruent, was verified using the Shapiro-Wilk test[44], where the variables showed a degree of significance of the test (p-value) greater than 0.05 (confidence interval), indicating that the variables tested have a normal distribution.

Repeated measures ANOVA analysis was used to analyze the Flanker Task and investigate the extent to which the interventions were able to certify Reaction Time (ms) and Accuracy (correct answers). The repeated measures t-test was used to compare heart rate between sessions. The model proposed by Cohen[45] was used to measure the effect size of the differences in the means of the two groups: Exergames - Just Dance® × Physical Education - Active Play).

Statistical significance of 0.05 was adopted in all analyses at an alpha level. The statistical procedures were analyzed using SPSS for Windows v. 26 (Statistical Package for Social Sciences, Chicago, IL, USA).

Results

Sample characterization data are presented as mean and standard deviation in Table 1.

Table 1 - Sample characterization (n = 9)

	Mean ± SD or n (%)
Age, years	8.6 ± 1.4
Weight, kg	35.7 ± 14.4
Height, cm	1.38 ± 0.12
BMI, kg/m^2	18.0 ± 4.9
Thinness	2 (22.2)
Normal weight	3 (33.3)
Overweigth/obese	4 (44.4)
KTK, score	95.8 ± 16.5
Normal coordination	6 (66.7)
Non-normal coordination	3 (33.3)
RAVEN, score	111.7 ± 16.6
Comorbidities	
Microcephaly	1 (11.1)

ADHD	4 (44.4)
CAPD	1 (11.1)
Interventions	
Psychologist	7 (77.8)
Speech Therapist	5 (55.6)
Occupational Therapist	3 (33.3)
Nutritionist	1 (11.1)
Psychomotricity	2 (22.2)
Education Support	3 (33.3)
Music Trerapy	1 (11.1)
Ecotherapy	1 (11.1)

BMI: Body Mass Index; KTK: Body Coordination Test for Children; RAVEN: Raven's Colored Progressive Matrices Test; ADHD: Attention deficit hyperactivity disorder; CAPD: Auditory central processing disorder.

Reaction Time, and Accuracy

In the statistical analysis, the Reaction Time and Accuracy scores in the Exergames - Just Dance®, Physical Education - active games and sedentary control sessions were analyzed using the ANOVA test. The assumption of homogeneity of variance was assessed using Levene's test. Bootstrapping procedures (1000 re-samples; 95% CI BCa) were carried out to obtain greater reliability of the results, to correct for deviations from the normal distribution of the sample and to obtain a 95% confidence interval for differences between the means46.

The incongruent reaction time (RT.i) showed a statistically significant difference in the scores of the three sessions, with a better result in the Exergames - Just Dance® session (849 (95% CI 642, 1057)) than in the Physical Education - Active Play session (938 (95% CI 684, 1191)) and the sedentary control session (969 (95% CI 742, 1196)). Therefore, after the lesson with the Just Dance® game, the children showed a better speed of response in inhibitory control than in the Physical Education lesson with active play.

The overall result of the ANOVA test found no statistically significant difference in the scores for Congruent Reaction Time (RT.c), Congruent Accuracy (Ac.c) and Incongruent Accuracy (Ac.i) in the three sessions (Table 2).

Table 2 - Acute effects of exergames and physical education on inhibitory control in children with autism spectrum disorder (n = 9)

	Control session Mean (95% CI)	Physical education session Mean (95% CI)	Exergame session Mean (95% CI)	P value	η^2
Congruent					
Reaction time, ms	879 (673, 1085)	829 (623, 1035)	775 (571, 978)	0.078	0.272
Accuracy, %	90.9 (77.7, 104.2)	87.9 (73.1, 102.6)	89.1 (77.2, 101)	0.305	0.138
Incongruent					
Reaction time, ms	969 (742, 1196)	938 (684, 1191)	849 (642, 1057)[a,b]	**0.022**	0.381
Accuracy, %	83.8 (72.7, 95.0)	72.8 (54.9, 90.8)	69.1 (43.5, 94.7)	0.056	0.302

[a] $p < 0.05$ compared to control session.

[b] $p < 0.05$ compared to physical education session.

Heart Rate

Heart rate was measured during aerobic exercise in the Exergames - Just Dance® and PE - Active play and analyzed using the paired Student's t-test, which computed the average of four measurements (5, 10, 15 and 20 minutes) and the total average of the exercises.

The observed frequencies (%) and 95% bootstrap confidence intervals (CI) were calculated. The children had a higher heart rate during physical education classes with active play. Physical education session 153.8 (95% CI 139.4, 168.0); exergames session 129.0 (95% CI 121.8, 135.6). With regard to % heart rate, in the physical education session 76.1 (95% CI 69.1, 83.3) and in the exergames session 63.9 (95% CI 60.3, 67.2).

According to the results, children achieved moderate intensity in the Exergames, 64% of the Maximum Heart Rate, and in PE, 76% of the Maximum Heart Rate.

Discussion

This exploratory study was designed to analyze the acute effects of three 20-minute sessions — one using Exergames, another a Physical Education class, and a sedentary control session — on the inhibitory control of school-aged children with ASD, using the Inhibitory Control Test (Flanker Task). The results highlight that, compared to the sedentary control session, both exercise sessions resulted in significant improvements in the children's reaction times. Notably, the Exergames session proved more effective than the Physical Education class in enhancing inhibitory control. These findings suggest that both Exergames and Physical Education classes are valuable resources, with considerable potential to improve inhibitory control in children with ASD.

Integrating playful activities such as games into exercise sessions has proven to be an effective strategy for improving inhibitory control and, consequently, academic performance in the classroom in neurotypical children[17]. Our study found similar results in children with ASD, where the physical education session that included playful activities showed significant improvements in inhibitory control. This finding is particularly relevant considering that children with ASD often face difficulties engaging in symbolic play due to delays in behavioral skills such as communication and socialization, as well as learning barriers like rigidity and repetitive behaviors[20]. These challenges can lead to social isolation and reduce the opportunities for these children to develop skills that traditional Physical Education activities promote alongside their peers[21,22]. These challenges underscore the importance of adapting Physical Education classes to meet the specific needs of children with ASD, employing alternative practices that can provide the same benefits.

Exergaming has been recognized as an alternative practice that can bring substantial benefits to children with (ASD, including improvements in physical fitness, executive function, and self-perception, as well as promoting greater participation in moderate to vigorous physical activities[25].

It has been suggested that even a single 20-minute session of exergames using platforms like Dance Dance Revolution and Cybercycling can result in significant improvements in executive function in young individuals with ASD[24]. Our study corroborated these findings by observing improvements in inhibitory control following an exergame session, highlighting exergames as a viable alternative to traditional physical activity programs for these children, especially in school settings. Incorporating exergames as part of regular physical activities in schools can provide a stimulating and engaging environment that aligns well with the specific needs of children with ASD, facilitating their active participation and engagement.

Previous studies suggest that moderate-intensity exercise can improve inhibitory control in children, with intensity being a crucial factor for this improvement. However, our study revealed that exergame sessions, despite being conducted at a lower intensity (64% of Maximum Heart Rate), resulted in superior inhibitory control compared to traditional physical education sessions (76% of Maximum Heart Rate). This suggests that the benefits of exergames may extend beyond physical intensity, possibly due to the cognitive effort required. These exercises require children to respond not only to the physical environment but also to the virtual one, processing multiple stimuli and making quick decisions, which promotes intense cognitive training. This training may activate brain areas linked to executive control more effectively than exercises that primarily focus on the physical aspect[46]. Therefore, future research should investigate more deeply the influence of cognitive load during physical activities and how it affects inhibitory control and academic performance, providing valuable insights for the development of educational interventions that benefit both the physical and cognitive well-being of children.

This study has limitations that warrant attention for the interpretation of findings and the planning of future research. The sample size, consisting of nine Brazilian children with ASD, is small and may affect the ability to generalize the results to a broader population. Subsequent studies could benefit from a larger sample size to enhance the robustness and external validity of the findings. Additionally, the inclusion criteria were limited to verbal children, excluding those with significant intellectual disabilities, which does not fully capture the diversity found within the autism spectrum. Future research should consider a wider range of participants with ASD to better reflect this diversity.

The results of this study are particularly significant as they demonstrate that exercise activities based on play and exergaming produce positive effects on inhibitory control in children with ASD. This finding is crucial because it highlights the potential for effectively incorporating these activities into the school context, providing opportunities for cognitive and physical

development in an inclusive and adaptive environment. Integrating these practices into the school curriculum can not only aid in the academic and social development of these children but also promote more active and fulfilling participation in physical activities, which are essential for their overall well-being.

In summary, only one session of the exergame Just Dance® or Physical Education had a potential and significant benefit on inhibitory control in children with ASD. The role of PE in these children's school life is very important, as physical activities help to improve executive functions. However, the use of exergames is still not very common in these classes. However, they can be used as a pedagogical intervention tool in PE classes to benefit the executive function of children with ASD as well as help these children achieve the recommended level of healthy physical activity. These games could be used without the need for a video game but with projection in the classroom of videos available on the internet.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplement 1. CONSORT 2010 checklist of information to include when reporting a clinical trial (adapted from http://www.consort-statement.org/).

Section/Topic	Item No	Checklist item	Reported on page No	Comments
Title and abstract				
	1a	Identification as a randomised trial in the title	1	Title and abstract should clearly indicate the trial design. Each journal has its own requirements on the structure of the abstract. Some journals also require the online clinical trial registration number included in the abstract.
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)		
Introduction				
Background and objectives	2a	Scientific background and explanation of rationale	1; 2; 3	Most of the times, introduction has three paragraphs. The first is the background, the second is the rationale, and the third is the hypothesis and objective.
	2b	Specific objectives or hypotheses		
Methods				
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	3	Study design, research location and duration, ethical approval, online registration should be placed in the first paragraph. Clearly defined inclusion and exclusion criteria of the study participant selection should be provided. Intervention method should be described in detail to allow the replication by other persons not involved in the present study. Every outcome reported
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons		
Participants	4a	Eligibility criteria for participants	4	
	4b	Settings and locations where the data were collected	4	
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4	
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed		
	6b	Any changes to trial outcomes after the trial commenced, with reasons		
Sample size	7a	How sample size was determined		
	7b	When applicable, explanation of any interim analyses and stopping guidelines		
Randomisation:				
Sequence generation	8a	Method used to generate the random allocation sequence	4	
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4	
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned		
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions		
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing		

		outcomes) and how		as the results of the clinical trial should be explained in the methods section. The definitions and methods to measure these outcomes should be explained.
	11b	If relevant, description of the similarity of interventions	6	
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	8	
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses		
Results				
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	8	CONSORT flow diagram should be placed in the first paragraph. Baseline characteristic comparisons should be the first Table presented. Number of participants finally analyzed should be mentioned together with the outcome presentations.
	13b	For each group, losses and exclusions after andomization, together with reasons		
Recruitment	14a	Dates defining the periods of recruitment and follow-up		
	14b	Why the trial ended or was stopped		
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	4	
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups		
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)		
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended		
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	8; 9	
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)		
Discussion				
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses		Limitations of the study should be discussed in the last paragraph, before the paragraph for conclusions.
Generalisability	21	Generalisability (external validity, applicability) of the trial findings		
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence		
Other information				
Registration	23	Registration number and name of trial registry	4	Some journals not only require an online registration but also ask to register the clinical trial before the patient enrollment (prospective registration). Some journals also require the trial registered in the specified trial registry.
Protocol	24	Where the full trial protocol can be accessed, if available		
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders		

Supplement 2: Intervention Songs - *Just Dance*® 2022

Music	Artist	Link	Tempo	Level
Mood	24kGoldn Ft. Iann dior	https://youtu.be/HG_zpcyyWvI	2’23’’	Light
Levitating	Dua Lipa	https://youtu.be/CDVnoU1Q_Zg	3’34’’	Medium
Freed from desire	GALA	https://youtu.be/ohRMRK3DTdY	3’30’’	Medium
Believer	Imagine Dragons	https://youtu.be/aoIh9zw5_Ms	3’28’’	Difficult
Last friday night	Katty Perry	https://youtu.be/ctzZDDrHNeQ	4’33’’	Difficult
		Total time of songs	20’50’’	
		Total rest time between songs	1’15’’	
		Total intervention time	22’05’’	

Source: Prepared by the author

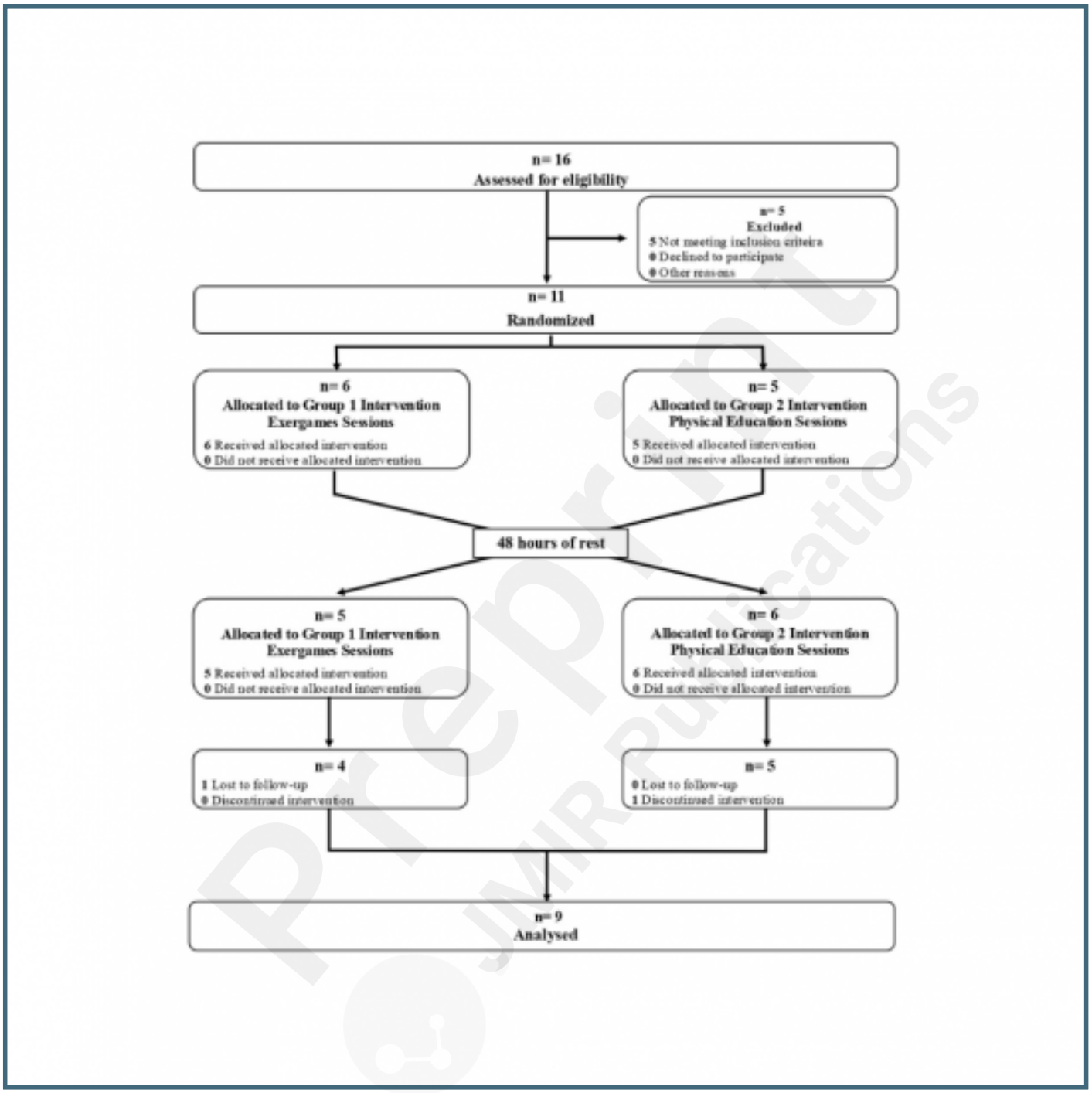
Supplement 3: Intervention Activities - Active Play

Games	Description	Time	Level
Statue of body parts	Teach the children the lyrics of the selected songs, explain that they should sing and move according to the music, when the music stops the teacher will speak two parts of the body through which they should come together (e.g. elbow on the knee, one student should put elbow on the knee of another student).	5'	Light
Save yourself with a hug	Explain to the students that one or more students will be the catchers, the others will have to run away and, in order not to be caught, they will have to hug their classmate, releasing soon after (you can stipulate the hug time of 5"), whoever is caught becomes the catcher. Variations: Allow hugs only between girls and boys. I only allow hugs between girls with girls and boys with boys. Hugs from three, four, five students.	5'	Medium
Hula dancing	Gather the class around hula hoops, arranged in a circle, in the middle of the court, turn on a song in fast or slow rhythm (varying the rhythms) and ask them to move through the hula hoops in rhythm with the music; At each interval of the song, a hula hoop is taken out and the student who does not receive a hula hoop must enter a hula hoop belonging to another classmate. At the end there will only be two hula hoops, the students spin around one and when the song ends, they enter the other hula hoop.	5'	Difficult
Pique Par, Pique Ímpar	The class will be divided into two teams (one team will be called "even" and the other "odd"). The activity will take place on a volleyball court. The teams will stand in the middle of the court, with one team back to back. The teacher will say a number, if it is "even", the students of the even team must run after the odd team, which must run away to the end of the volleyball court. When students on the odd team cross the baseline, they can no longer be caught. Each student caught will move on to the other team. When all students have passed the bottom line, they should return to the activity start line and then restart the activity with the teacher saying another number. The teacher can do the activity using mathematical operations and the result of this will be considered as the beginning of the activity.	5'	Difficult
	Total playing time	20'	
	Total rest time between games	2'05"	
	Total intervention time	22'05"	

Source: Prepared by the author

Supplementary Files

Untitled.


n= 16
Assessed for eligibility
n= 5
Excluded
5 Not meeting inclusion criteira
0 Declined to participate
0 Other reasons
n= 11
Randomized
n= 6
Allocated to Group 1 Intervention
Exergames Sessions
6 Received allocated intervention
0 Did not receive allocated intervention
n= 5
Allocated to Group 2 Intervention
Physical Education Sessions
5 Received allocated intervention
0 Did not receive allocated intervention
48 hours of rest
n= 5
Allocated to Group 1 Intervention
Exergames Sessions
5 Received allocated intervention
0 Did not receive allocated intervention
n= 6
Allocated to Group 2 Intervention
Physical Education Sessions
6 Received allocated intervention
0 Did not receive allocated intervention
n= 4
1 Lost to follow-up
0 Discontinued intervention
n= 5
0 Lost to follow-up
1 Discontinued intervention
n= 9
Analysed

Untitled.