International Journal of Psychiatry Research

ISSN Print: 2664-8962
ISSN Online: 2664-8970
Impact Factor: RJIF 5.44
IJPR 2025; 7(1): 05-11
www.psychiatryjournal.in
Received: 06-10-2024
Accepted: 12-11-2024

Fabrício Bruno Cardoso
Laboratory of Educational Innovations and Neuropsychopedagogical Studies (LIEENP), Faculdade CENSUPEG, Joinville, Brazil

Filipe M Bonone
Laboratory of Educational Innovations and Neuropsychopedagogical Studies (LIEENP), Faculdade CENSUPEG, Joinville, Brazil

Lucianara Braga
Laboratory of Educational Innovations and Neuropsychopedagogical Studies (LIEENP), Faculdade CENSUPEG, Joinville, Brazil

Washington Adolfo Battista
Laboratory of Educational Innovations and Neuropsychopedagogical Studies (LIEENP), Faculdade CENSUPEG, Joinville, Brazil

Aliny Carvalho Dematté
Núcleo de Divulgação Científica e Ensino de Neurociências (NuDCEN), Instituto de Biofísica Carlos Chagas Filho (IBCCF), Programa de Neurobiologia, Universidade Federal do Rio de Janeiro, Brazil

João Vitor Galo Esteves
Núcleo de Divulgação Científica e Ensino de Neurociências (NuDCEN), Instituto de Biofísica Carlos Chagas Filho (IBCCF), Programa de Neurobiologia, Universidade Federal do Rio de Janeiro, Brazil

Alfred Sholl-Franco
Núcleo de Divulgação Científica e Ensino de Neurociências (NuDCEN), Instituto de Biofísica Carlos Chagas Filho (IBCCF), Programa de Neurobiologia, Universidade Federal do Rio de Janeiro, Brazil

Corresponding Author:
Fabrício Bruno Cardoso
Laboratory of Educational Innovations and Neuropsychopedagogical Studies (LIEENP), Faculdade CENSUPEG, Joinville, Brazil

Effects of a Neuropsychopedagogical motor intervention program on executive functions in children with autism spectrum disorder: A double-blind controlled study

Fabrício Bruno Cardoso, Filipe M Bonone, Lucianara Braga, Washington Adolfo Battista, Aliny Carvalho Dematté, João Vitor Galo Esteves and Alfred Sholl-Franco

DOI: https://doi.org/10.33545/26648962.2025.v7.i1a.79

Abstract

Background: Autism Spectrum Disorder (ASD) is a neurodevelopmental condition associated with deficits in executive functions (EF) and reaction times, which are critical for learning and social interaction. Movement-based interventions have shown promise in improving these abilities in children with ASD.

Objective: This double-blind, controlled study aimed to evaluate the effects of the Neuropsychopedagogical Motor Intervention Program (NMIP) on executive functions and reaction times in children with ASD.

Materials and methods: A total of 107 children with ASD, aged 7 to 8 years, were randomly assigned to experimental (n = 64) and control (n = 43) groups. The NMIP, consisting of 36 sessions, focused on enhancing motor coordination, cognitive flexibility, and inhibitory control through structured activities. EF was assessed using the Head-Toes-Knees-Shoulders (HTKS) test, and reaction times were measured using the Reaction Time Ruler Test. Pre- and post-intervention assessments were conducted in a blinded manner.

Results: The experimental group showed a 61.34% improvement in HTKS scores compared to 16.69% in the control group ($p < 0.01$). Reaction times in the experimental group decreased by 39.98%, compared to 10.01% in the control group ($p < 0.01$). Statistical analysis confirmed significant differences between groups, with the experimental group demonstrating superior outcomes in both HTKS and reaction time performance.

Conclusion: The NMIP significantly enhanced EF and reduced reaction times in children with ASD, highlighting its potential as an effective and accessible intervention. The findings emphasize the importance of movement-based programs in promoting cognitive and motor development. Further research is needed to explore the long-term effects of the NMIP and its applicability in diverse cultural settings.

Keywords: Autism spectrum disorder, children, executive functions, neuropsychopedagogy

Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition that affects millions of children worldwide. With a rising prevalence, estimated at 1 in 36 children, ASD underscores the importance of interventions that promote the holistic development of this population [1, 2]. The condition is characterized by persistent deficits in social communication and restricted, repetitive behaviors. Furthermore, it is frequently associated with significant challenges in executive functions (EF) and motor skills, both of which are critical for learning, self-regulation, and social interaction [3, 4].

Executive functions, encompassing processes such as inhibitory control, working memory, and cognitive flexibility, play a pivotal role in child development, influencing academic performance, emotional regulation, and problem-solving abilities [5, 6]. In children with ASD, EF deficits have been consistently reported, including difficulties with planning, self-monitoring, and response inhibition, compared to typically developing peers matched in IQ and language level [7, 8].

These deficits also have long-term implications, potentially leading to challenges in adulthood, such as limitations in independent behavior and professional performance [9, 10].

Simultaneously, the relationship between motor skills and cognitive development has been widely explored, highlighting that motor development is directly linked to neural plasticity and the strengthening of brain networks responsible for cognition and attention [11-13]. Research suggests that the simultaneous development of these skills is most prominent between the ages of 5 and 10, emphasizing the importance of early interventions [4, 14].

In this context, interventions that integrate motor and cognitive activities have emerged as effective strategies to address deficits in children with ASD [15]. These interventions, in addition to simultaneously activating the prefrontal cortex and cerebellum, can be applied in naturalistic contexts, facilitating the generalization of learned skills [16, 17]. Furthermore, exercises requiring greater cognitive engagement, as proposed by the cognitive stimulation hypothesis have shown better outcomes in enhancing cognitive abilities compared to simple, repetitive motor activities [18, 19].

Conversely, more technologically integrated approaches, such as computer-based or pharmacological treatments, although demonstrating positive outcomes, face limitations related to high costs, specialized equipment, and the need for trained professionals [20, 21]. In contrast, sports interventions offer an accessible, effective, and low-cost alternative, showing benefits in improving executive functions and modulating brain networks in children with ASD [22].

While recent studies highlight the potential of movement-based programs, such as "Coordenando-se," in promoting motor and cognitive skills, significant gaps remain in the literature [21, 23]. Few studies have robustly investigated the effects of programs that combine motor and cognitive challenges to enhance executive functions in children with ASD [22-25]. Thus, this study aims to evaluate the effects of a Neuropsychopedagogical Motor Intervention Program (NMIP) on the executive functioning of children with ASD, using a double-blind, controlled experimental design.

Materials and Methods

Participants

Initially, this study included 209 children with Autism Spectrum Disorder (ASD), consisting of 102 girls and 107 boys, aged between 7 and 8 (±7,67) years. All children were from the southern region of Brazil.

Participant selection adhered to strict inclusion and exclusion criteria, as outlined below:

- Children with a confirmed diagnosis of Autism Spectrum Disorder (ASD) according to the DSM-V-TR, validated through clinical assessment and the ADOS-2, conducted by a qualified evaluator. Additionally, the children must meet the criteria for Level 1 support, characterized by minimal assistance required for daily activities, as defined by the DSM-V-TR.
- Ages between 7 and 8 years.
- Intelligence Quotient (IQ) ≥ 70.
- Diagnosis established for more than 2 years.
- Regular participation in multidisciplinary treatment (e.g., occupational therapy, psychology, speech therapy, among others).
- Absence of significant auditory or visual impairments.
- No severe psychiatric or neurological comorbidities, such as epilepsy.
- No history of cranial trauma, severe physical disabilities, or major organ diseases in the past two years.
- Approval from a medical supervisor to participate in the study.

After applying the inclusion and exclusion criteria, the G*Power calculation was used to define key parameters as follows: (1) medium-to-large effect size (Cohen's f = 0.30), (2) statistical power of 0.85 (85%), (3) significance level of alpha = 0.05, and (4) a repeated measures analysis of variance with two groups (Experimental and control). Based on these parameters, the required sample size was reduced, and the available sample of 107 children (48 girls and 59 boys) was more than sufficient to ensure statistical robustness. The children were randomly assigned to two groups: 43 (16 girls and 27 boys) in the control group and 64 (32 girls and 32 boys) in the experimental group.

Assessment Procedures

The assessment of the participants was conducted at two distinct moments: before (pre-intervention) and after (post-intervention) the intervention period. All assessments were carried out in a spacious, well-lit, and ventilated room, ensuring a comfortable and distraction-free environment. The sessions were filmed to allow for detailed and precise analysis of the collected data.

For the assessment of EF, the Head-Toes-Knees-Shoulders (HTKS) test and the Reaction Time Ruler Test, an instrument widely used to assess the speed of motor responses to visual stimuli.

Evaluations were conducted at two distinct time points: before (1st Evaluation – 1st EV) and after (2nd Evaluation – 2nd EV) the intervention period. The test was always administered by a properly trained evaluator who was blinded to the participants' group allocation (Control or experimental), ensuring procedural impartiality and minimizing biases.

a) Head-Toes-Knees-Shoulders (HTKS)

The Head-Toes-Knees-Shoulders (HTKS) test, was used to evaluate inhibitory control, working memory, and cognitive flexibility [26]._The test was administered in a spacious, well-ventilated, and well-lit room, ensuring a comfortable and distraction-free environment. To ensure data collection accuracy, all test sessions were filmed, allowing for a detailed recording of responses.

The test consisted of three parts: Part I: Included basic commands ("touch your head" or "touch your feet"). Children who scored at least 4 points advanced to the next stage; Part II: Introduced additional commands ("touch your knees" or "touch your shoulders"), increasing the level of complexity; Part III: Modified the associations between commands and responses, requiring greater cognitive flexibility and inhibitory control.

The administration followed the original HTKS protocol, with initial practice instructions provided to ensure understanding of the rules. Scoring was based on the accuracy of responses:_Correct response immediately: 2 points;_Self-correction: 1 point;_Incorrect response: 0 points These stages were carried out following the established protocol, with no feedback provided during the test sessions, ensuring consistent conditions for all participants.

b) Reaction Time Ruler Test

The Reaction Time Ruler Test, a widely used instrument, was employed to assess how quickly participants responded to visual stimuli. During the test, the child was seated in a chair with both feet in full contact with the floor, ensuring a stable posture. The child's preferred hand was positioned near their mouth, with fingers slightly open in a pinch-like motion, ready to grasp the ruler [24].

The procedure involved the evaluator holding a 100 cm ruler vertically, with the zero mark aligned to the bottom of the child's fingers. Without prior warning, the ruler was released, and the child was required to react by catching it as quickly as possible upon perceiving the visual stimulus. The distance traveled by the ruler before being caught was recorded in centimeters and subsequently converted to reaction time (In seconds) using a specific conversion table.

Each participant completed 20 attempts, divided into two sets of 10 trials, with a 1-minute interval between sets to prevent fatigue. The average reaction times were calculated to provide an accurate measure of each child's motor response capacity.

Intervention Procedures

The Neuropsychopedagogical Motor Intervention Program (NMIP) comprises 24 activities grounded in motor development theory, designed to significantly support children's cognitive growth [21]. The program emphasizes activities that enhance hand and foot coordination by focusing on the coding and decoding of body movements using cards with geometric shapes and colors. Its primary aim is to promote motor development, executive functions, and mindfulness. The NMIP consists of 36 sessions, each lasting 15 minutes, conducted by a properly trained member of the research team in adherence to the theoretical principles of the "Coordenando-se" methodology. All activities were implemented in a spacious, well-lit room, ensuring an appropriate and distraction-free environment.

The "Coordenando-se" (Translated as "Coordinating") activities involve matching specific colored shapes to body parts, requiring the child to observe the color and shape and position the corresponding body part accordingly. This method builds on a previous study conducted with children experiencing learningdifficulties, demonstrating its potential to enhance motor and cognitive skills [21, 24].

Fig 1: Implement the Neuropsychopedagogical Motor Intervention Program (NMIP) in a classroom setting. (A) displays a directive from the NMIP's initial session, where a child, upon viewing a green square, is to balance solely on their left foot, and upon seeing a blue square, to balance solely on their right foot. (B) advances to the tenth NMIP session, where the complexity of directives increases: the green square continues to signify balancing on the left foot, the blue square for the right foot, the pink square for tapping both feet, the blue circle for elevating the right arm, the green circle for lifting only the left arm, the pink circle for raising both arms, and the small pink circle indicates clapping. In (C), we observe children executing these initial directives from the first NMIP session. Finally, (D) presents children performing the advanced directives from the NMIP's tenth session.

Statistical Analysis

Statistical analysis was conducted using parametric tests appropriate to the study's objectives. Initially, descriptive analyses were performed to characterize the variables of interest within each group (Experimental and control), including means, standard deviations, minimum, and maximum values. To evaluate differences between the pre- and post-intervention periods within each group, paired t-tests were used to identify significant improvements in executive functions and reaction times. Additionally, independent t-tests were applied to compare performance between the experimental and control groups at each time point.

Statistical significance was set at $p < 0.05$, with specific values reported for greater precision. Furthermore, 95% confidence intervals for the differences and standard errors of the mean were calculated. The coefficient of determination (R^2) was used to estimate the proportion of variance explained by the intervention, while the F-test assessed the homogeneity of variances between groups.

All analyses were performed using the GraphPad Prism 10 statistical software, ensuring the robustness and validity of the results. This approach allowed for the evaluation of the intervention's impact on both groups and facilitated comparisons of their performance over time.

Results

The results of the Executive Function Assessment using the HTKS test were analyzed at two time points: before and after the intervention for the control and experimental groups. In the 1st evaluation (1^{st} EV) (Pre-intervention), the control group presented scores ranging from 14 (Minimum) to 35 (Maximum), with an average of 26.43. Conversely, the experimental group scored between 13 (Minimum) and 32 (Maximum), with a slightly lower average of 23.85. These results indicate that, prior to the intervention, the experimental group had a lower average performance compared to the control group, suggesting a more challenging starting point.

In the 2^{nd} evaluation (2^{nd} EV) (post-intervention) (Figure 2), the control group presented scores ranging from 19 (Minimum) to 39 (Maximum), with an average of 30.84 ($p < 0.01$). Meanwhile, the experimental group showed substantial improvement, with scores ranging from 25 (Minimum) to 50 (Maximum) and achieving a significantly higher average of 38.48.

A comparison between the two groups demonstrated that, while the control group experienced an average improvement of 4.41 points (representing a percentage increase of approximately 16.69%), revealed by a paired t-test (t = 3.535, df = 42, $p < 0.01$), the experimental group recorded a much more significant average increase of 14.63 points, equivalent to a percentage improvement of approximately 61.34%. This result was also significant, as indicated by a paired t-test (t = 13.61, df = 63, $p < 0.01$).

These findings highlight that children in the experimental group benefited more significantly from the INPP intervention compared to the control group. Thus, the intervention demonstrated a more substantial impact on the experimental group, suggesting it may be particularly effective in improving executive functions in children with ASD, as assessed by the HTKS test.

To reinforce this conclusion, a statistical analysis comparing the results of the Experimental and Control groups using an independent t-test confirmed a statistically significant difference between the groups, with a p-value < 0.0001. The mean difference between the two groups was 7.638±1.254 (mean ± standard error), with a 95% confidence interval ranging from 5.152 to 10.12, underscoring the magnitude of this difference.

The coefficient of determination (R^2) was 0.2611, indicating that approximately 26.11% of the variation in results could be explained by the differences between the groups. Additionally, the F-test, which compared the variances of the two groups, found no significant differences in variances (P = 0.2054), indicating that the result distributions across the groups were comparable in terms of variability.

These statistical results corroborate the previously described averages, reinforcing that the experimental group experienced significantly greater improvements than the control group, highlighting the efficacy of the NMIP for children with ASD.

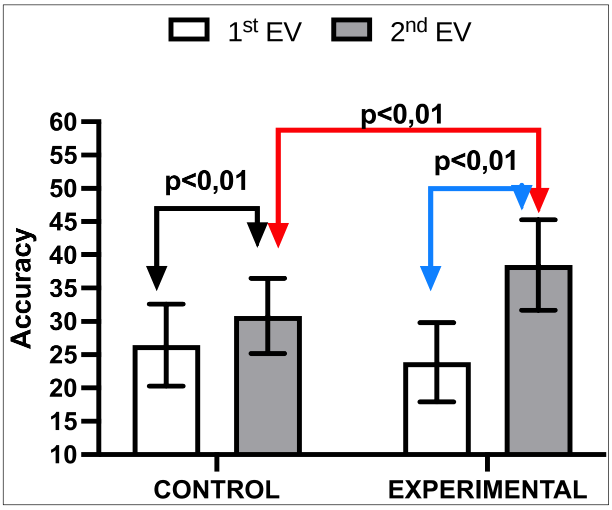

Fig 2: Comparison of Executive Function Performance between Control and Experimental Groups across Two Evaluations

Bar graph comparing executive function performance between two groups of children over two evaluations (1^{st} and 2^{nd} Evaluations – EV). Black arrow: Pre- and post-test comparison (1st and 2nd Evaluation) in the Control Group; Blue arrow: Pre- and post-test comparison (1^{st} and 2^{nd} Evaluation) in the Experimental Group; Red arrow: Intergroup comparison (Control Group vs. Experimental Group) at each evaluation. Data presented as mean and standard deviation.

When evaluated for Reaction Time, during the 1st evaluation (1^{st} EV), the control group exhibited reaction times ranging from 0.3894 seconds (Minimum) to 0.5149 seconds (Maximum), with an average of 0.4557 seconds. Similarly, the experimental group showed reaction times ranging from 0.3895 seconds (Minimum) to 0.5297 seconds (Maximum), with an average of 0.4596 seconds (Figure 3). These data indicate very similar initial performances

between the two groups, with comparable means and minimum and maximum values.
During the 2nd evaluation (2nd EV), the control group showed improvement, with reaction times reduced to a range of 0.3505 seconds (Minimum) to 0.4634 seconds (Maximum), resulting in an average of 0.4101 seconds. The experimental group demonstrated an even more significant improvement, with reaction times reduced to a range of 0.2337 seconds (Minimum) to 0.3178 seconds (Maximum), achieving an average of 0.2758 seconds.

A comparison of the means between the evaluations shows that the control group experienced an average reduction of 0.0456 seconds, representing an improvement of approximately 10.01%. A paired t-test revealed a t-value of 83.61 with a degrees of freedom (df) of 42, and a p-value < 0.01. In contrast, the experimental group exhibited a much more substantial average reduction of 0.1838 seconds, corresponding to an improvement of approximately 39.98%. The paired t-test showed a t-value of 88.72 with a df of 63, and a p-value < 0.01.

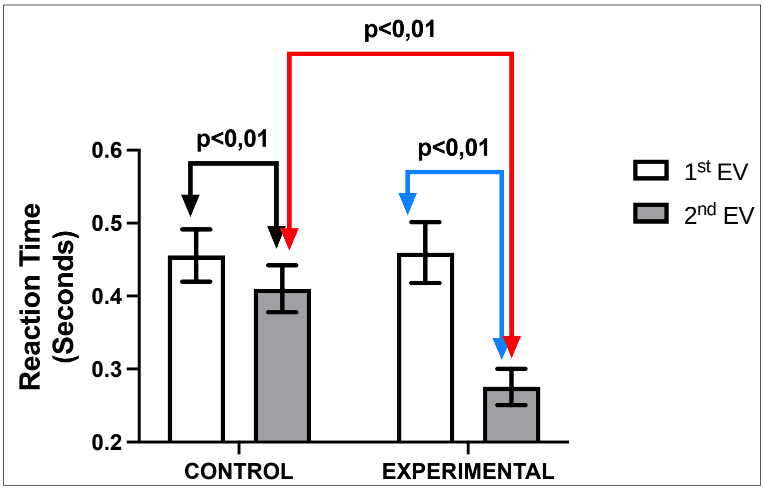

Fig 3: Comparison of Motor Reaction Time Performance between Control and Experimental Groups across Two Evaluations

Bar graph comparing motor reaction time performance between two groups of children over two evaluations (1st and 2nd Evaluations – EV); Black arrow: Pre- and post-test comparison (1st and 2nd Evaluation) in the Control Group; Blue arrow: Pre- and post-test comparison (1st and 2nd Evaluation) in the Experimental Group; Red arrow: Intergroup comparison (Control Group vs. Experimental Group) at each evaluation. Data are presented as mean and standard deviation.
The data clearly show that the experimental group outperformed the control group in reaction times. This significant difference reinforces the idea that children in the experimental group benefited substantially from the NMIP. The unpaired t-test confirmed that this difference is statistically significant, with a p-value < 0.0001, effectively eliminating the likelihood of the result occurring by chance. The mean difference between the two groups was -0.1344±0.005524 (mean ± standard error), with a 95% confidence interval ranging from -0.1453 to -0.1234, demonstrating that the reaction times of the experimental group were significantly faster. Furthermore, the coefficient of determination (R^2) was 0.8493, indicating that nearly 85% of the variation in reaction times can be attributed to differences between the groups. Although the F-test revealed that variances between the groups were not significantly different (P = 0.0630), this further reinforces the consistency and reliability of the improvements observed in the experimental group. These results underscore the positive impact of the NMIP, particularly in enhancing attention and executive functions in children with ASD.

Discussion

The results of this study demonstrate the positive impact of the MNIP on executive functions in children with ASD. These findings highlight the effectiveness of structured interventions that integrate movement and cognition, as widely discussed in the literature on ASD.
The 61.34% improvement in HTKS test scores observed in the experimental group underscores the effectiveness of the MNIP program in advancing EF, including working memory, inhibitory control, and cognitive flexibility. These improvements align with evidence suggesting that adapted physical interventions strengthen the prefrontal cortex and promote neural plasticity [27, 28]. Studies indicate that structured exercises, particularly those combining motor and cognitive activities, have a significant impact on improving EF, fostering essential skills for academic learning and everyday life [27-30].
Furthermore, evidence suggests that cognitive training programs focused on working memory tasks and cognitive flexibility are effective in children with ASD, indicating that specific interventions have the potential to mitigate executive deficits associated with the condition [31-34].
The 39.98% reduction in reaction times observed in the experimental group is significant, highlighting improvements in processing speed and sustained attention. Evidence suggests that movement-based interventions reduce stereotyped behaviors and enhance body awareness and coordination, thereby improving the ability of these children to perform executive function tasks, such as the Reaction Time Ruler Test [35, 36]. Similarly, adapted sports programs have been shown to significantly improve motor responsiveness and cognitive functions [37].
Motor deficits are directly linked to cognition in children with ASD, and early interventions have the potential to mitigate these challenges [38]. This finding is supported by evidence associating improvements in reaction times with the activation of sensorimotor networks during structured interventions [38, 39].

The statistically significant difference between the experimental and control groups, with a p-value < 0.01, reinforces the superiority of the INPP program over traditional approaches. This efficacy is supported by comparisons between physical and virtual training methods, which concluded that movement-based approaches provide consistent advantages for children with ASD [29]. Similar results have also been observed in adapted programs, such as judo, showing improvements in psychosocial and motor skills [10].

Finally, the literature highlights that motor interventions not only promote advances in cognitive functions but also reduce stereotyped behaviors and improve social interactions [40]. Evidence shows that regular exercise provides significant gains in executive and social skills in children with ASD, supporting the findings of this study [37]. Moreover, the role of movement properties in fostering motor and cognitive skills within a safe and motivating environment is emphasized [35].

Conclusion

The results of this double-blind, controlled study highlight the effectiveness of the Neuropsychopedagogical Motor Intervention Program (NMIP) in improving executive functions and reducing reaction times in children with ASD. The significant improvements observed in the experimental group underscore the potential of movement-based integrative interventions to promote cognitive and motor development in populations with specific needs.

Furthermore, the substantial reduction in stereotyped behaviors and advancements in sustained attention and inhibitory control suggest that the NMIP is an effective and accessible approach to enhance essential functional skills in children with ASD. These findings align with the literature, which emphasizes the importance of programs integrating movement and cognition as valuable tools for early interventions.

The rigorous double-blind, controlled design of this study strengthens the reliability of the findings, supporting the broader adoption of movement-based programs in educational and therapeutic contexts for children with ASD. Future studies should explore the application of the NMIP in diverse cultural settings and assess its long-term effects on other populations with developmental challenges.

Acknowledgments

We extend our heartfelt thanks to all the parents and professional partners who supported this study. Special gratitude is also expressed to the Associação de Amigos dos Autistas (AMA) of Santa Catarina for their invaluable collaboration.

References

1. Bougeard C, Picarel-Blanchot F, Schmid R, Campbell R, Buitelaar J. Prevalence of autism spectrum disorder and co-morbidities in children and adolescents: A systematic literature review. Focus (Am Psychiatr Publ). 2024;22(2):212-228
2. Fan MSN, Li WHC, Ho LLK, Phiri L, Choi KC. Nature-based interventions for autistic children: A systematic review and meta-analysis. JAMA Netw Open. 2023;6(12):e2346715.
3. Diamond A. Executive functions. Annu Rev Psychol. 2013;64:135-168.
4. Ruffini C, Bei E, Pecini C. Socio-emotional behavior, learning, and the distinct contributions of Executive Functions in primary graders. Eur J Psychol Educ. 2024;39:4249-4273.
5. Townes P, Liu C, Panesar P, Devoe D, Lee SY, Taylor G, *et al*. Do ASD and ADHD have distinct executive function deficits? A systematic review and meta-analysis of direct comparison studies. J Atten Disord. 2023;27(14):1571-1582
6. Christoforou M, Jones EJH, White P, Charman T. Executive function profiles of preschool children with autism spectrum disorder and attention-deficit/hyperactivity disorder: A systematic review. JCPP Adv. 2023;3(1):e12123.
7. Yeung MK, Bai J, Mak KL. Longitudinal changes in executive function in autism spectrum disorder: A systematic review and meta-analyses. Autism Res. 2024;17(10):2045-2063.
8. Dehnavi F, Khan A. Executive function among adults with autism spectrum disorder: An eye-tracking study. Appl Neuropsychol Adult. 2024, 1-13.
9. Oberer N, Gashaj V, Roebers CM. Executive functions, visual-motor coordination, physical fitness and academic achievement: Longitudinal relations in typically developing children. Hum Mov Sci. 2018;58:69-79.
10. Morales C, Dolan SC, Anderson DA, Anderson LM, Reilly EE. Exploring the contributions of affective constructs and interoceptive awareness to feeling fat. Eat Weight Disord. 2022;27(8):3533-3541.
11. Baker AE, Galván A, Fuligni AJ. The connecting brain in context: How adolescent plasticity supports learning and development. Dev Cogn Neurosci. 2025;71:101486.
12. Maksimović S, Marisavljević M, Stanojević N, Ćirović M, Punišić S, Adamović T, *et al*. Importance of early intervention in reducing autistic symptoms and speech-language deficits in children with autism spectrum disorder. Children (Basel). 2023;10(1):122.
13. Ibbotson P. The development of executive function: Mechanisms of change and functional pressures. J Cogn Dev. 2023;24(2):172-190.
14. Müller A, Bába ÉB, Židek P, Lengyel A, Lakó JH, Laoues-Czimbalmos N, *et al*. The experiences of motor skill development in children with autism spectrum disorder (ASD) reflected through parental responses. Children (Basel). 2024;11(10):1238.
15. Ehrhardt SE, Wards Y, Rideaux R, Marjańska M, Jin J, Cloos MA, *et al*. Neurochemical predictors of generalized learning induced by brain stimulation and training. J Neurosci. 2024;44(21):e1676232024.
16. Pfeiffer DL, Landa RJ. Assessing generalization during professional development in child care: A pilot randomized controlled trial. Early Child Educ J. 2024;52:87-99.
17. Yang Z, Zhu L, He Q, Li X, Zhang J, Tang Y. The relationship between acute aerobic exercise and inhibitory control in college students: The impact of physical and cognitive engagement. Physiol Behav. 2025;290:114779.
18. Zehnder C, Gasser M, Anzeneder S, Martin-Niedecken AL, Pesce C, Schmidt M, *et al*. Together towards better executive functions? Effects of acute cognitively

demanding physical activity and social interaction on inhibition. Ment Health Phys Act. 2024;27:100640.
19. Cardoso FB, Loureiro VS, Souza S, Pinheiro J, Fulle A, Russo RMT, *et al*. The effects of neuropsychopedagogical intervention on children with learning difficulties. Am J Educ Res. 2021;9(11):673-677.
20. Cardoso F, Braga L, Loureiro V, Bonone F, Souza S, Sholl-Franco A. Neuropsychopedagogical motor intervention program strengthening inhibitory control, working memory, and language abilities in post-COVID-19 school returnees. J Educ Train Stud. 2024;12(3):1-11.
21. Hou Y, Wang Y, Deng J, Song X. Effects of different exercise interventions on executive function in children with autism spectrum disorder: A network meta-analysis. Frontiers in psychiatry. 2024;15:1440123.
22. Cardoso FB, Braga L, Bonone FM, Algarve F, Defreyn E, Justi NS, *et al*. Impact of a neuropsychopedagogical motor program on executive functions and language skills in preschoolers. SCIREA J Educ. 2025;10(1):1-19.
23. Wang JG, Cai KL, Liu ZM, Herold F, Zou L, Zhu LN, *et al*. Effects of mini-basketball training program on executive functions and core symptoms among preschool children with autism spectrum disorders. Brain Sci. 2020;10(5):263.
24. Pasqualotto A, Mazzoni N, Bentenuto A, Mulè A, Benso F, Venuti P. Effects of cognitive training programs on executive function in children and adolescents with autism spectrum disorder: A systematic review. Brain Sci. 2021;11(10):1280.
25. McClelland MM, Cameron CE, Connor CM, Farris CL, Jewkes AM, Morrison FJ. Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. Dev Psychol. 2007;43:947-59.
26. Cardoso FB, Carenzi T, Batista WA. Teste de tempo de reação com régua. Joinville: Faculdade Censupeg; c2024.
27. Sung YS, Loh SC, Lin LY. Physical activity and motor performance: a comparison between young children with and without autism spectrum disorder. Neuropsychiatr Dis Treat. 2021;17:3743-3751.
28. Li X, Qu X, Shi K, Yang Y, Sun J. Physical exercise for brain plasticity promotion: an overview of the underlying oscillatory mechanism. Front Neurosci. 2024;18:1440975.
29. Ji C, Yang J, Lin L, Chen S. Executive function improvement for children with autism spectrum disorder: A comparative study between virtual training and physical exercise methods. Children (Basel). 2022;9(4):507.
30. Akil M, Tokay B, Güngör MG. Cognitive health outcomes of fundamental motor skill applications in children through cooperative learning method. BMC Psychol. 2024;12:522.
31. Maurya R, Faijullah Khan M. Effect of cognitive training program in children with autism spectrum disorder: An experimental study: Cognitive skills training program. Int J Spec Educ. 2022;37(1):75-84.
32. Kou R, Zhang Z, Zhu F, Tang Y, Li Z. Effects of exergaming on executive function and motor ability in children: A systematic review and meta-analysis. PLoS One. 2024;19(9):e0309462.
33. Jesus AC, Menezes AKM, Santos ACA, Santos DS, Conceição KNL, Sousa DS. Benefits of physical activity for children with autism spectrum disorder. Res Soc Dev. 2024;13(7):e2013746235.
34. Hatfield DP, Must A, Kennedy W, Staiano AE, Slavet J, Sabelli RA, *et al*. GamerFit-ASD beta test: Adapting an evidence-based exergaming and telehealth coaching intervention for autistic youth. Front Pediatr. 2023;11:1198000.
35. Faraji S, Najafabadi MG, Zandi HG, Parent-Nichols J. Water-based exercise therapy and improvement in the motor skills and cognitive function of children with autism spectrum disorder: A commentary. Russ Open Med J. 2022;11:e0112.
36. Ye Y, Ning K, Wan B, Shangguan C. The effects of the exercise intervention on fundamental movement skills in children with attention deficit hyperactivity disorder and/or autism spectrum disorder: A meta-analysis. Sustainability. 2023;15(6):5206.
37. Suárez-Manzano S, Ruiz-Ariza A, de Loureiro NEM, Martínez-López EJ. Effects of physical activity on cognition, behavior, and motor skills in youth with autism spectrum disorder: A systematic review of intervention studies. Behav Sci (Basel). 2024;14(4):330.
38. Hatipoğlu Özcan G, Özer DF, Pınar S. Effects of motor intervention program on academic skills, motor skills and social skills in children with autism spectrum disorder. J Autism Dev Disord. 2024.
39. Kurz MJ, Taylor BK, Heinrichs-Graham E, Spooner RK, Baker SE, Wilson TW. Motor practice related changes in the sensorimotor cortices of youth with cerebral palsy. Brain Commun. 2024;6(5):fcae332
40. Li L, Wang A, Fang Q, Moosbrugger ME. Physical activity interventions for improving cognitive functions in children with autism spectrum disorder: Protocol for a network meta-analysis of randomized controlled trials. JMIR Res Protoc. 2023;12:e40383.