A multicomponent exercise program for executive functions in children with ASD: a pilot multiple case study

Programa de ejercicio físico multicomponente sobre las funciones ejecutivas en niños con TEA: estudio piloto de casos múltiples

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Received: 15-04-26
Accepted: 30-05-26

Hoo cite in APA

Conesa-Molina, M., Pablos, A., Grau, M. D., & Elvira, L. (2026). A multicomponent exercise program for executive functions in children with ASD: a pilot multiple case study. *Retos, 84*, 46-62. https://doi.org/10.47197/retos.v83.119902

Abstract

Introduction: There is scientific evidence indicating positive effects on executive functions in autism, but with certain limitations.
Objective: The present pilot multiple case study obtained preliminary estimates of the effects of a multicomponent physical exercise program on executive functions in children with Autism Spectrum Disorder Level 1.
Methodology: Twenty-one children (13 in the experimental group, 8 in the control group) between 8 and 12 years old participated. Executive functions were assessed using the Behavior Rating Inventory of Executive Function (BRIEF-2) in two naturalistic contexts: at home and at school. The Jacobson and Truax Reliable Change Index was used to identify clinical responders, along with the Number Needed to Treat (NNT).
Results: 45,5 % of participants in the experimental group showed clinically significant improvement in at least one setting, compared to no participants in the control group (NNT = 2.20, 95% CI 1.58 to ∞). Differentiated response patterns were identified according to the assessment context, with a greater effect on the school environment (d = -.53) than at home (d = -.45).
Conclusions: The results are consistent with the hypothesis that multicomponent physical exercise could be a viable intervention to improve executive functions in children with Level 1 ASD, although contextual generalization represents a more ambitious therapeutic goal. Definitive conclusions about efficacy await replication in adequately powered confirmatory trials.

Keywords

Autism spectrum disorder; BRIEF-2; executive functions; children; physical exercise; multiple case study; number needed to treat.

Resumen

Introducción: Existe evidencia científica que indica efectos positivos sobre las funciones ejecutivas en el autismo, pero con ciertas limitaciones.
Objetivo: El presente estudio piloto de casos múltiples obtuvo estimaciones preliminares de los efectos de un programa de ejercicio físico multicomponente sobre las funciones ejecutivas en niños con trastorno del espectro autista nivel 1.
Metodología: Participaron veintiún niños (13 en el grupo experimental y 8 en el grupo control) de entre 8 y 12 años. Las funciones ejecutivas se evaluaron utilizando el inventario BRIEF-2 en dos contextos naturalistas: en casa y en la escuela. El índice de cambio fiable de Jacobson y Truax se utilizó para identificar a los respondedores clínicos, junto con el número necesario para tratar.
Resultados: El 45,5% de los participantes del grupo experimental mostró mejoría clínicamente significativa en al menos un entorno, en comparación con ningún participante del grupo control (NNT = 2.20, IC 95% 1.58 a ∞). Se identificaron patrones de respuesta diferenciados según el contexto de la evaluación, con un mayor efecto en el entorno escolar (d = -.53) que en casa (d = -.45).
Conclusiones: Los resultados son consistentes con la hipótesis de que el ejercicio físico multicomponente podría ser una intervención viable y eficaz para mejorar las funciones ejecutivas en niños con trastorno del espectro autista de nivel 1, aunque la generalización contextual representa un objetivo terapéutico más ambicioso. Las conclusiones definitivas sobre la eficacia requieren replicación en ensayos confirmatorios con potencia estadística adecuada.

Palabras clave

Trastorno del espectro autista; BRIEF-2; funciones ejecutivas; niños; ejercicio físico; estudio de casos múltiples; número necesario para tratar.

Introduction

Executive functions encompass abilities such as working memory, inhibition, planning, impulse control, flexibility, attentional shifting, initiation, and self-regulation. Located primarily in the prefrontal cortex, these functions coordinate mental processes that resolve internal and external problems (Miyake et al., 2000). Executive functions develop gradually from the first year of life, with peaks of performance during childhood and adolescence, followed by stabilization in adulthood and eventual decline with aging (Diamond, 2013). Deficits in executive functioning have been observed both in populations with acquired frontal lobe damage and in developmental disorders such as autism, supporting the executive dysfunction hypothesis of Autism Spectrum Disorder (Ozonoff et al., 1991). Neuroimaging studies reveal atypical frontal lobe development in autism, including early cortical overgrowth followed by accelerated gray matter decline, as well as altered structure and connectivity in dorsolateral and medial prefrontal regions (Carper & Courchesne, 2005; Ong & Fan, 2023). Children and adolescents with ASD exhibit a delayed neurodevelopmental trajectory of executive function maturation compared to typically developing peers (Sadozai et al., 2024).

Educational context

In educational settings, students with autism experience difficulties in executive functions such as working memory, planning, mental flexibility, and inhibition (Ryan & Marshall, 2018). These challenges arise from demands imposed by conventional classrooms on students with ASD, including changes in schedules and environments, comprehension of complex instructions, and task initiation and completion. Teachers who facilitate task sequencing, the use of visual supports, and the organization of schedules and spaces play a key role in supporting learning (Darretxe & Sepúlveda, 2011). However, when support is excessive, it may prevent students from developing independence, denying them tools and opportunities to manage tasks autonomously (Ryan & Marshall, 2018). Structured environments, complemented by evidence-based pedagogical strategies (visual supports, predictable routines, and work systems), have been associated with improvements in cognitive flexibility, working memory, and planning in students with autism (Mesibov et al., 2005; Virues-Ortega et al., 2013).

Family and social context

Executive function difficulties significantly impact family and social contexts. Problems in managing social challenges, often linked to deficits in emotional control and cognitive flexibility, can trigger frustration and elevated anxiety levels, and correlate with high stress levels in parents of children with ASD (Costescu et al., 2024). Deficits in emotion regulation in children with autism have been conceptualized as a transdiagnostic mechanism underlying aggression, self-injury, anxiety, and depression (Mazefsky et al., 2013), and impairments in working memory and emotional control have been associated with greater family difficulties. Empirical evidence shows that middle childhood executive functioning, particularly behavioral regulation, mediates the pathway between early childhood autism symptoms and adolescent externalizing behaviours and adaptive functioning (Ameis et al., 2022). There is scientific evidence of greater emotional dysregulation, a narrower range of adaptive strategies, and more intense and prolonged emotional reactions compared to typically developing children (McDonald et al., 2024), underscoring the need for ecological interventions that target executive functions in natural contexts.

Need for effective interventions

Effective strategies for managing executive function deficits include personalized schedules, predictable routines, clear spatial boundaries, and visual supports, complemented by consistent assessment methods (Darretxe & Sepúlveda, 2011). The TEACCH methodology encompasses physical structure, individualized schedules, work systems, visual routines, and task organization (Mesibov et al., 2005; Virues-Ortega et al., 2013). The literature highlights the importance of ecologically contextual interventions, since parent and teacher assessments capture demands differently at home and school (Gentil-Gutiérrez et al., 2022).

The Behavior Rating Inventory of Executive Function, Second Edition (BRIEF-2; Gioia et al., 2015) is an internationally recognized instrument with clinical scales grouped into three regulation indices plus the Global Executive Composite (GEC): the Behaviour Regulation Index (BRI; Inhibit and Self-Monitor), the

Emotional Regulation Index (ERI; Shift and Emotional Control), and the Cognitive Regulation Index (CRI; Initiate, Working Memory, Plan/Organize, Task-Monitor, and Organization of Materials).

Physical Exercise and Executive Function

Scientific evidence demonstrates positive effects of physical exercise on executive functions in children with autism (Hou et al., 2024; Liang et al., 2022). A recent network meta-analysis showed that different sports exhibit varying effectiveness across executive domains: mini-basketball, exercise programs, martial arts, bicycle riding, table tennis, and Neiyang Gong excelled in improving cognitive flexibility and inhibitory control, while table tennis, bicycle riding, and martial arts proved most effective for working memory (Hou et al., 2024). Recent evidence also suggests that cognitively challenging physical activity, particularly through nonlinear pedagogy, can produce significant improvements in executive functions in school contexts (Kaloka et al., 2024).

The choice of a multicomponent approach is grounded in the need to simultaneously address multiple domains of executive functions (behavioral, emotional, and cognitive regulation) and in evidence suggesting that integrated programs combining aerobic exercise, motor coordination, and cognitive-motor tasks produce effects more transferable to naturalistic contexts (Liang et al., 2022; Rivera et al., 2025).

Motor competence correlates directly and significantly with school participation in children with autism, whereas school participation shows an inverse correlation with executive function metacognition and behavioral regulation (Kheirollahzadeh et al., 2021).

While there is growing evidence on the benefits of physical exercise in children with ASD (Rivera et al., 2025), most studies have included heterogeneous samples in terms of ASD severity, limiting the generalizability of findings to specific support levels. Furthermore, analyses have predominantly focused on group-level measures, with little attention to individual response variability and contextual generalization (Liang et al., 2022).

A recent scoping review of school-based physical activity programs for children with ASD found that cognitive and psychosocial function was among the most frequently studied outcomes, with a higher percentage of articles reporting positive effects (Robles et al., 2023).

Objectives

The present work was conceived as a pilot multiple case study designed to (a) obtain preliminary estimates of the magnitude and variability of effects of a multicomponent physical exercise program on executive functions in children with Level 1 ASD, (b) explore individual response patterns through case-level reliable change and within-subject effect-size indices, (c) quantify intervention effects using Number Needed to Treat (NNT) analyses, and (d) inform the design and a priori sample size calculation of a subsequent adequately powered confirmatory randomized controlled trial.

Primary objective: To obtain preliminary estimates of the effects of a multicomponent physical exercise program on global executive functions (Global Executive Composite of BRIEF-2) in children with Level 1 ASD, using a pilot multiple case study design.

Secondary objectives:

- To analyze the contextual specificity of the response to the intervention by comparing home and school-based assessments.
- To identify individual response patterns through reliable change indices and within-subject effect sizes per responder.
- To quantify the magnitude of the effect of the intervention using the Number Needed to Treat (NNT).
- To explore the mechanistic pathways through behavioral, emotional, and cognitive regulation indices (BRI, ERI, and CRI).

Method

This pilot study utilized a hybrid design combining a pre-post quasi-experimental controlled comparison with an aggregated case-level analysis. Between-group comparisons followed an intention-to-treat framework, while individual response patterns were examined following Single-Case Experimental Design (SCED) reporting standards (Kratochwill et al., 2023). This approach aligns with methodological recommendations for pilot studies, aiming to yield preliminary estimates of effect size and response variability to inform a future definitive randomized controlled trial.

Participants

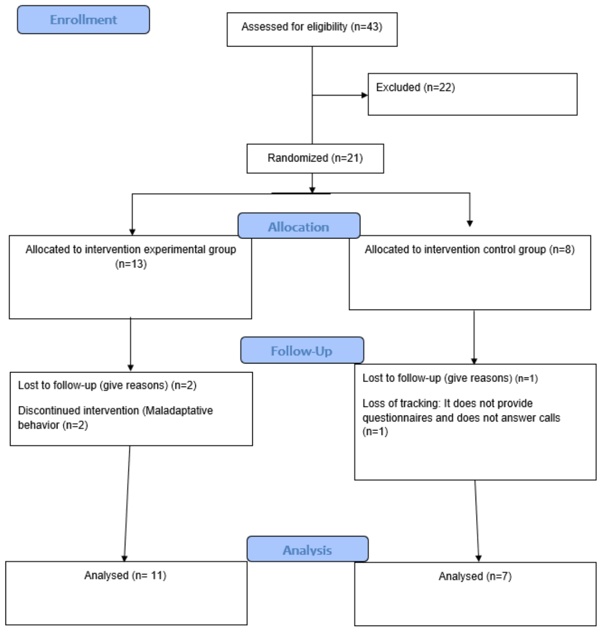
Because this is a pilot study, sample size was not determined by priori statistical power. The convenience sample included all eligible children with Level 1 ASD who agreed to participate during the recruitment period, yielding an analytical sample of N = 21 (Experimental = 13, Control = 8). The effect sizes derived from this study (within-subject Cohen's d, between-group Cohen's d, and Number Needed to Treat) will be used to inform the power calculation and sample size estimation of the future confirmatory trial.

Participants were consecutively enrolled and allocated to either the experimental or control group based on logistical accessibility to the intervention site. Due to the preliminary nature of this pilot study and its small sample size, formal randomization was not implemented (a methodological limitation that increases the potential for selection bias). During the 12-week study period, the control group maintained their usual school and family routines without receiving any structured physical exercise intervention or active control activity. To minimize assessment bias, the statistician responsible for outcome analyses remained blinded to group allocation until the primary analyses were finalized.

Inclusion criteria required participants to: (a) be between 8 and 12 years of age, (b) have a clinical diagnosis of ASD Level 1 confirmed by the ADI-R (Lord et al., 1994) and ADOS (Lord et al., 2000), and (c) complete the 12-week program. Exclusion criteria included: (a) bone fractures within the previous six months, (b) a clinical diagnosis of anxiety disorder requiring anxiolytic medication, or (c) current participation in competitive sports.

Of the 21 enrolled participants, three (Experimental: Ex7, Ex12; Control: C4) did not provide post-intervention data and were excluded from the pre-post change analyses, yielding a retained sample of 18 participants (86% retention) who completed the entire protocol. Specifically, 18 participants provided full pre-post data within the family context (Experimental, n = 11; Control, n = 7), and 17 provided school data (Experimental, n = 11; Control, n = 6); participant C6 contributed only family data. The complete participant flow is detailed in Figure 1. A complete-case approach was adopted for the primary analyses without data imputation, and a worst-case sensitivity analysis is subsequently reported in the Results section.

Figure 1. Flow diagram



Source: Authors' own elaboration.

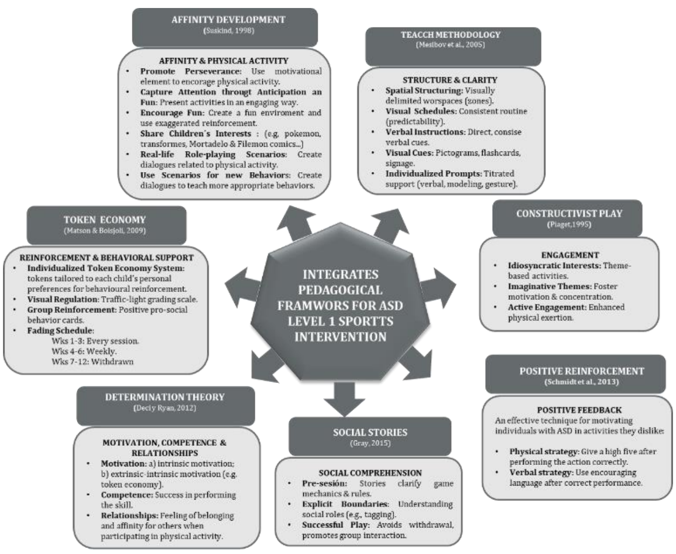
Procedure

The Catholic University of Valencia research ethics committee approved all procedures (reference number: UCV/2021-2022/124), and participants provided informed consent. Assessments were conducted during the week prior to the start of the intervention and repeated in the week immediately following its conclusion.

The multicomponent physical exercise program was administered over 12 weeks, consisting of two 60-minute sessions per week. Sessions were delivered in an inclusive group format led by two trained professionals, maintaining a strict 2:7 professional-to-participant ratio. Each group was composed of 3-4 children with ASD and 2-3 neurotypical peers, a configuration intentionally designed to foster social interaction, peer-modeling, and naturalistic social inclusion.

To accommodate the specific cognitive and behavioral profiles of Level 1 ASD populations, seven evidence-based pedagogical frameworks were integrated into the sports context (Figure 2).

Figure 2. Integrated pedagogical frameworks for ASD Level 1 sports intervention.



Source: Compiled by the authors from the cited theoretical frameworks (Deci & Ryan, 2012; Gray, 2015; Matson & Boisjoli, 2009; Mesibov et al., 2005; Piaget, 1995; Schmidt et al., 2013; Suskind, 1998)

All intervention sessions followed a standardized, predictable sequence divided into specific training components (Table 1).

The development of the multicomponent physical exercise program for children with level 1 autism was structured in three phases distributed over 12 weeks. Its methodological development is as follows:

– Phase 1 Adaptation (weeks 1-2): Its objective is to introduce children progressively to the different routines and dynamics.
– Phase 2 Development (weeks 3-5): The objective is to progressively increase the level of demand for the workload. After consolidating the dynamics of the sessions, the demand in each of the activities is progressively increased.
– Phase 3 Consolidation (week 6-12): The goal is to maintain and optimize performance. The consolidation of routines allows the workload to be maintained while increasing the demands with the aim of maximizing physical adaptations.

Table 1. Standardized Structure of the Multicomponent Exercise Sessions.

Session Component	Duration	Target Objectives & Methodological Content
Introduction & Adaptation	~5 min	Initial greeting, review of the TEACCH visual schedule, and behavioral priming.
Warm-up	~10 min	Low-intensity dynamic movements to prepare physiological systems
Physical & Motor Module	20–30 min	Activities targeting aerobic capacity, speed, strength, fine/gross motor skills, balance, accuracy, and catching.
Cognitive Training Module	20–30 min	Motor-cognitive dual-tasks targeting core executive functions (inhibitory control, working memory, and cognitive flexibility)
Cool down	~10 min	Anxiety management via Koeppen's (1974) progressive muscle relaxation adapted through a narrative motor story.
Closure	~5 min	Final reflection, token economy review, and dismissal greeting

Minimum thresholds for prior attendance were established, requiring participants to attend at least 75% of scheduled sessions to be included in the primary outcome analyses. Attendance was recorded at each session and communicated weekly to families, implementing strategies to address attendance barriers when participants approached the threshold.

Instrument

Global Executive Composite (GEC) in two contexts (home and school) were assessed using the Spanish adaptation of the BRIEF-2 (Gioia et al., 2015; Spanish adaptation: Maldonado et al., 2017). This instrument analyzes executive function through nine clinical scales (Inhibition, Self-Supervision, Flexibility, Emotional Control, Initiative, Working Memory, Planning and Organization, Task Monitoring, and Materials Organization), three general indices (BRI, ERI, CRI), and the Global Executive Composite (GEC). The Spanish adaptation demonstrates adequate internal consistency, with a mean Cronbach's α of .86 across scales (Maldonado et al., 2017).

Data analysis

Analyses were conducted using IBM SPSS Statistics for Windows, version 28.0 (IBM Corp., Armonk, NY, USA), with figures generated using Python 3.11 with matplotlib 3.7 (Hunter, 2007).

The Global Executive Composite (GEC) was calculated as GEC = BRI + ERI + CRI, following standard BRIEF-2 procedures (Gioia et al., 2015; Spanish adaptation: Maldonado et al., 2017).

Baseline between-group equivalence was assessed using independent-samples t-tests. Effect sizes were computed at two levels. For individual change, Cohen's d was calculated as $d = (X_2 - X_1) / SD_{normative}$, where SD normative = 10.

For group-level pre-post effects, Morris's d (Morris, 2008) was used with 95% confidence intervals.

Clinical significance at the individual level was assessed using the Reliable Change Index (Jacobson & Truax, 1991): RCI = $(X_2 - X_1)$ / SEM, with SEM = 3.5 for the BRIEF-2 GEC based on the test-retest reliability reported in the Spanish adaptation manual (Maldonado et al., 2017). Participants with $|RCI| \geq 1.96$ were classified as showing clinically significant change (improvement, deterioration, or stability). The Number Needed to Treat was calculated as NNT = 1 / (EER − CER), where EER and CER are the experimental and control responder rates.

Between-group differences in responder rates were tested using Fisher's exact test. Effect size interpretation followed Cohen (1988; small ≥ .20, medium ≥ .50, large ≥ .80). All tests were two-tailed with α = .05.

All tests were two-tailed with α = .05. To evaluate the robustness of the responder-rate contrast to the assumption of missing completely at random, a worst-case sensitivity analysis was pre-specified. The three excluded participants were assigned values unfavorable to the study hypothesis: no post-intervention change for the two Experimental participants (Ex7, Ex12) and a clinically significant improvement (RCI = −2.5) for the Control participant (C4). Responder rates and Fisher's exact test were then recomputed on the resulting full sample (N = 21).

Results

Sample Features and Missing Data Management

The final analytical sample comprised 18 participants with complete pre-post data (Experimental, n = 11; Control, n = 7); one control participant (C6) contributed only family-context data. Baseline analyses were performed with the complete recruited sample (Experimental, n = 13; Control, n = 8).

Table 2 presents demographic and baseline characteristics. No statistically significant differences were found between groups at baseline (Family: t (18) = -1.47, p = .159; School: t (18) = -.260, p = .798), indicating comparability.

A notable finding was the marked heterogeneity of executive profiles. Baseline GEC scores ranged from normal functioning to severe impairment in both contexts, consistent with executive function phenotypes in ASD. A pre-specified worst-case sensitivity analysis was conducted to evaluate the robustness of the primary findings to the assumption of missing completely at random. Under the conservative scenario described in the Method, 5 of 13 Experimental participants (38.5%) showed clinically significant improvement in at least one setting, compared to 1 of 8 Control participants (12.5%; Fisher's exact p = .336; NNT = 3.85). The direction of the between-group contrast was preserved, supporting the conclusion that the primary results are not driven by selective attrition, although the loss of statistical significance reinforces the preliminary nature of the findings and the need for replication in adequately powered trials.

Table 2. Participant Demographic and Baseline Characteristics by Group

Variable	Experimental (*n* = 13)	Control (*n* = 8)
Age, M ± SD	10.1 ± 1.3	10.1 ± 1.2
Sex (F/M)	0/13	1/7
GEC-Family, M ± SD	72.9 ± 9.4	67.3 ± 4.8
GEC-School, M ± SD	66.0 ± 11.4	64.6 ± 12.3
Years since diagnosis, M ± SD	6.7 ±2.4	5.9±2.3
Comorbidities, *n* %		
Yes	8 (61.5%)	3 (37.5%)
No	5 (38.5%)	5 (62.5%)
Current medication. *n* %		
Yes	7 (53.8%)	3 (37.5%)
No	6 (46.2%)	5 (62.5%)

Note. GEC = Global Executive Composite; M = mean; SD = standard deviation.

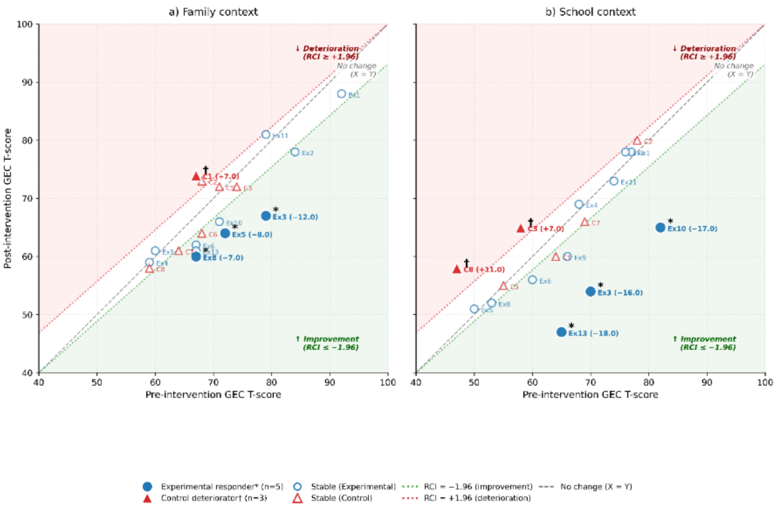
Individual Change Analysis

Pre-post changes in Global Executive Composite (GEC) T-scores for the 18 participants with complete data in at least one context are visualized as scatter plots in Figure 3.

Across the experimental group, mean within-group pre-post effect sizes were d = −0.45 (95% CI [−.73, −.18]) for the family context and d = −0.53 (95% CI [−1.06, .003]) for the school context, indicating small to medium effects (Cohen, 1988). In contrast, the control group showed negligible effects of d = +0.04 (95% CI [−.34, .43]) and d = +0.22 (95% CI [−.40, .83]), suggesting no benefit and potentially opposite trends.

Three participants in the control group (C1, C3, and C8) showed clinically significant deterioration, with RCI values of +2.00, +2.00, and +3.11, respectively, and no control participant showed clinically significant improvement in either context. Because the between-group difference in responder rates did not reach conventional statistical significance (see Clinical Responder Analysis below), this contrast should be interpreted as descriptive evidence consistent with a clinically meaningful pattern rather than as a demonstration of intervention efficacy. It is, however, informative regarding the natural course of executive function in untreated Level 1 ASD over a 12-week period, which in this sample appeared to be stagnation or worsening rather than spontaneous improvement.

Figure 3. Individual pre-post change in Global Executive Composite (GEC) T-scores of the BRIEF-2 across family (a) and school (b) assessment contexts.



Note: * experimental-group responders; † control-group participants with clinically significant deterioration; hollow markers denote participants whose changes did not exceed the RCI threshold. Numerical Δ values next to solid markers indicate the T-score change from pre to post.

Clinical Responder Analysis

Table 3 presents the distribution of responders according to clinically significant change criteria. In the experimental group, 5 of 11 participants with complete data (45.5%) reached the responder threshold in at least one setting, while no participants in the control group (0%) showed clinically significant improvement in either setting. Responder rates were compared between groups using Fisher's exact test (two-sided). The proportion of clinical responders differed between groups (5/11 experimental vs. 0/7 control), but this difference did not reach conventional statistical significance (Fisher's exact p = .101, OR not estimable due to zero events in the control group). This non-significant result reflects the limited statistical power of the pilot sample (estimated at approximately 31%) and is consistent with the preliminary nature of the study; the observed responder pattern should therefore be interpreted as hypothesis-generating rather than as evidence of intervention efficacy, awaiting confirmation in adequately powered trials.

Contextual specificity of response: Distinct patterns were identified in the experimental group:

- Total success (both contexts). Participant Ex3 (9.1%) showed clinically significant improvement in both settings, with reductions of 12 and 16 T-score points (RCI = -3.43 and RCI = -4.57, both $p < .001$).

- Contextualized response at school. Participants Ex10 and Ex13 (18.2%) showed clinically significant improvement exclusively in the school setting, with reductions of 17 and 18 T-score points (RCI = -4.86 and RCI = -5.14, both $p < .001$).

- Contextualized response in the family. Participants Ex5 and Ex8 (18.2%) showed clinically significant improvement exclusively in the family context, with reductions of 8 and 7 T-score points (RCI = -2.29 and RCI = -2.00, both $p < .05$).

Table 3. Responder Classification by Group and Context

Group	n	Total Success	School Only	Family Only	Non-Responder	Total (%)
Experimental	11	1 (9.1%)	2 (18.2%)	2 (18.2%)	6 (54.5%)	5 (45.5%)
Control	7	0 (0%)	0 (0%)	0 (0%)	7 (100%)	0 (0%)

Note: Control n=6 for school-context analyses (C6 missing school data)

Multiple Case Analysis: Patterns of Response

Following the logic of systematic replication across cases (Yin, 2018), four representative case-level responder analyses are presented: one generalized responder, two family-only responders, two school-only responders, and three control-group deteriorators. Each pattern is described in detail with GEC T-scores, Reliable Change Indices (RCI), and within-subject Cohen's d effect sizes with 95% CI. The selection of these cases followed a maximum-variation sampling strategy aimed at illustrating the range of response patterns observed in the experimental and control groups, rather than probabilistic generalization.

Pattern 1: *Generalized improvement* (Participant Ex3). This participant, with moderate to severe initial severity (GEC-F = 79, GEC-E = 70), achieved the greatest improvements in both contexts: reductions of 12 T-points in family (RCI = -3.43, $p < .001$) and 16 T-points in school (RCI = -4.57, $p < .001$). The effect sizes were d = -1.20 (95% CI [-1.83, -0.57]) and d = -1.60 (95% CI [-2.32, -0.88]) respectively.

Pattern 2: Family-only improvement (Participants Ex5, Ex8). Two participants showed clinically significant improvement exclusively in the family context.

- Ex5: Greatest contextualized improvement in the family with an 8-point reduction in family T-score (RCI = -2.29, $p < 0.05$; d = -0.80, 95% CI [-1.42, -0.18]), while school scores remained essentially stable (Δ = -1 T-point).

- Ex8: Moderate baseline impairment (GEC-F = 67, GEC-E = 53) with clinically significant improvement in family (RCI = -2.00, $p < .05$; d = -.70, 95% CI [-1.31, -.09]), but minimal change in school (Δ = +1 T-point).

Pattern 3: School-only improvement (Participants Ex10, Ex13). Two participants showed clinically significant improvement exclusively in the school context.

- Ex10: Severe baseline deterioration in school (GEC-E = 82). Intervention produced a reduction of 17 T-points (RCI = -4.86, $p < 0.001$; d = -1.70, 95% CI [-2.44, -0.96]), from 98th to 91st percentile, while home change was subclinical (Δ = +5 T-points, RCI = -1.43).

- Ex13: Slight baseline elevation in school (GEC-S = 65) but no clinical range. Achieved clinically significant improvement in school: reduction of 18 T-points (RCI = -5.14, $p < .001$; d = -1.80, 95% CI [-2.54, -1.06]), from 63rd to 16th percentile. Family context showed minimal change (Δ = -6 T-points, RCI = -1.71, subclinical).

Pattern 4: Deterioration in the absence of intervention (Control C1, C3, C8). Three control participants showed clinically significant deterioration (RCI ≥ |1.96|) in the absence of intervention, illustrating natural variability without intervention:

- C1: 7-point increase in family executive symptomatology (GEC-F = 67→74, RCI = +2.00, $p < .05$; d = +.70, 95% CI [-.07, 1.47]), moving from moderate to severe profile.

- C3: 11-point increase in school GEC (GEC-S = 58→65, RCI = +2.00, $p < .05$; d = +.70).

- C8: 11-point increase in school GEC (GEC-S = 47→58, RCI = +3.11, $p < 0.01$; d = +1.10).

- C2: Subclinical worsening trend (GEC-F = 68→73, RCI = +1.43; GEC-S = 78→80, RCI = +.57).

Together with the stable controls (C5, C7), four of seven control participants showed unfavorable trajectories in the absence of the intervention.

Magnitude of Effect and Contextual Specificity

Among experimental group responders (n = 5), the pattern of change varied by context. In the school setting, the mean change was -10.2 T-score points (range: -18 to +1), with a mean effect size of d = −1.02. In the family context, the mean change was -7.6 T-points (range: -12 to -5), with d = -0.76. This gradient of effects suggests that the multicomponent exercise program produced greater improvements in the school context, where executive regulation demands are more structured and predictable.

Number Needed to Treat (NNT)

Clinical effectiveness analysis using NNT indicated that 2.2 participants are needed to obtain a single clinical responder in at least one setting (NNT = 2.20, 95% CI [1.58, ∞]) (table 4). To achieve full success (improvement in both settings), NNT increased to 11.0 (95% CI: [6.18, ∞]), reflecting that contextual generalization is a more ambitious therapeutic goal.

Table 4. Program Effectiveness Summary

Measure	Value	95% CI	Interpretation
NNT (any context)	2.20	[1.6, ∞]	Good clinical utility
NNT (both contexts)	11.0	[6.2, ∞]	Ambitious goal
Effect size (Family)	d = -.45	[-.73, -.18]	Small-medium
Effect size (School)	d = -.53	[-1.06, .003]	Small-medium
Responder rate (Exp)	45.5%	[16.8, 76.7]	Clinically meaningful

Note. NNT = Number Needed to Treat; CI = confidence interval.

Preliminary findings on BRIEF-2 component indices

Although this study focused on the Global Executive Composite, the available data on component indices provide insights into underlying mechanisms. Table 5 presents changes in BRIEF-2 component scales among clinical responders.

School-improving responders (Ex10, Ex13) showed the greatest improvements in CRI and BRI at school, with changes ranging from -14 to -22 T-scores. Family-based responders (Ex5, Ex8) showed greater improvements in ERI, with gains of -6 to -19 points in the family context. The participant with generalized response (Ex3) showed balanced improvements in all components in both contexts.

Exploratory Spearman correlation analyses revealed that changes in CRI showed a moderate to strong positive correlation with GEC changes in the family context (r = .700, p = .104), and a strong positive correlation in the school context (r = .975, p = .005). These exploratory analyses with n = 5 should be interpreted with caution given the very small sample size.

Table 5. Changes in BRIEF-2 component indices in clinical responders

ID	ΔBRI F	ΔERI F	ΔCRI F	ΔBRI S	ΔERI S	ΔCRI S	ΔGEC F	ΔGEC S	Pattern
Ex3	-8	-13	-10	-13	-17	-13	-12	-16	Generalized
Ex5	-2	-19	-2	-2	-3	+4	-8	+1	Family
Ex8	0	-6	-8	+8	-12	-1	-7	-1	Family
Ex10	-8	-6	-1	-18	-13	-13	-5	-17	School
Ex13	-8	0	-7	-14	-9	-22	-6	-18	School
M ±SD	-5.2 ± 3.9	-8.8 ± 7.3	-5.6 ± 3.9	-7.8 ± 10.6	-8.0 ± 7.0	-9.0 ± 10.4	-7.6 ± 2.7	-10.2 ± 9.4	-
r ΔCRI F/S	-.224	.718	.700	.800	-.100	.975 *	-	-	-

Note. BRI = Behavior Regulation Index; ERI = Emotional Regulation Index; CRI = Cognitive Regulation Index; Δ = post-pre-difference (negative values indicate improvement); F = family context; S = school context.

Discussion

Interpretation of Main Findings

The present pilot multiple case study examined the preliminary effects of a multicomponent physical exercise program on executive functions in children with Level 1 ASD. The 45.5% clinical responder rate in the experimental group, compared to no response in the control group, provides preliminary evidence of a clinically meaningful therapeutic effect; however, given the non-significant Fisher's exact test ($p = .101$) and the limited statistical power of the pilot, these results should be interpreted as hypothesis-generating rather than as confirmation of efficacy. The NNT of 2.20 for any response context, although suggestive, falls below the conventional threshold of NNT < 10 typically used to denote a clinically worthwhile intervention (Citrome, 2008); yet, in the absence of statistical significance for the responder-rate comparison, this NNT estimate should likewise be interpreted with caution and replicated in larger trials before being used to inform clinical or policy decisions. The observed effect sizes ($d = -.45$ to $-.53$) are consistent with those reported in meta-analyses of exercise interventions on executive functions in children with ASD (Liang et al., 2022; Rivera et al., 2025) and with multimodal physical activity programs implemented in educational contexts (Vallejos-Meriño et al., 2024).These findings align with the broader literature suggesting that exercise interventions may produce meaningful improvements in executive functioning among children with neurodevelopmental disorders (Hou et al., 2024), although the present pilot does not allow us to establish a causal claim of efficacy.

In line with these findings, a recent scoping review of school-based physical activity programs for students with ASD reported that cognitive and psychosocial outcomes were among the domains with the highest proportion of positive results (Robles et al., 2023), supporting the plausibility of the present observations while underscoring the need for more rigorous experimental designs in the field.

A descriptive finding of interest is that four of seven control participants showed unfavorable trajectories over the 12-week period, three reaching clinical significance for deterioration and one with a subclinical trend. This pattern is consistent with the literature suggesting that executive function deficits in ASD can persist or worsen over time without targeted support, following a delayed neurodevelopmental trajectory (Ameis et al., 2022; Sadozai et al., 2024). This observation is consistent with the notion that the control condition approximates the natural course of EF maturation in this population, although the small control sample size precludes strong inference and the finding should be replicated in larger studies.

Contextual Specificity of Response

One of the most distinctive findings was the identification of differentiated response patterns according to the evaluation context. The observed effect gradient (greater in school: $d = -.53$ vs. home: $d = -.45$) suggests that the physical exercise program produced more pronounced improvements in the structured school environment.

This contextual specificity can be explained through multiple mechanisms. First, the school environment presents more explicit and consistent executive demands, which may facilitate detection of subtle improvements; the cognitive activation triggered by structured tasks may be particularly relevant for academic demands (Hillman et al., 2008). Second, the familiarity of the home context may reduce the need for executive resources, masking potential improvements. Third, school-based settings impose explicit rules, sequential tasks, and constant demands for attentional change, which align with the executive functions most impaired in ASD, specifically cognitive flexibility and planning (Blijd-Hoogewys et al., 2014).

Previous research underscores the ecological and contextual nature of executive function in children with ASD (Gentil-Gutiérrez et al., 2022), and the BRIEF-2 framework explicitly recognizes that the BRI, ERI, and CRI capture functionally distinct domains that may respond differently to environmental demands (Gioia et al., 2015). Variability in regulation indices according to context should not be interpreted as measurement inconsistency, but as a reflection of differentiated functional demands. This finding supports the theoretical framework proposed by integrative models of executive function (Ameis et al., 2022), which posits that executive functioning is highly context-dependent and that interventions must account for environmental specificity.

The identification of exclusively school-based or home-based responders has important implications for clinical practice: (a) intervention effect assessment must include multiple contexts, as informant discrepancies are meaningful (Gentil-Gutiérrez et al., 2022); (b) therapeutic objectives must be individualized; and (c) contextual generalization should not be automatically assumed.

Preliminary Findings on BRIEF-2 Component Indices

Although the present pilot study was not powered to detect changes in the Global Executive Composite, exploratory analyses of component indices provide preliminary mechanistic insight into the differential response patterns. School-improving responders (Ex10, Ex13) showed the greatest improvements in the Cognitive Regulation Index and Behaviour Regulation Index at school, with reductions of 14 to 22 T-score points. In contrast, family-based responders (Ex5, Ex8) showed the greatest improvements in the Emotional Regulation Index in the family context (-6 to -19 T-points). The participant with generalized response (Ex3) showed balanced improvements across all components in both contexts.

This pattern is consistent with the BRIEF-2 conceptual framework, in which the BRI, ERI, and CRI capture functionally distinct domains (Gioia et al., 2015), and with evidence that the Shift scale (part of the CRI) captures some of the most clinically meaningful impairments in ASD (Blijd-Hoogewys et al., 2014). Specifically, Spearman correlation analyses revealed that changes in CRI showed a strong positive correlation with GEC changes in the school context ($r = .975$, $p = .005$), suggesting that school-context improvement may be differentially associated with gains in cognitive regulation rather than with isolated improvements in behavioral or emotional domains. Conversely, family-context improvements appeared to be primarily driven by changes in emotional regulation, in line with literature linking the family environment to frequent demands for emotional self-regulation due to unpredictability, affective intensity, and frequency of social interactions (Costescu et al., 2024; Mazefsky et al., 2013).

Number Needed to Treat (NNT)

The NNT analysis revealed a meaningful distinction between obtaining a clinical response in any single context (NNT = 2.20, 95% CI [1.58, ∞]) and obtaining generalized improvement across both contexts (NNT = 11.0, 95% CI [6.18, ∞]). The latter, less favorable NNT reflects that contextual generalization. where improvements transfer across both school and home environments, is a more ambitious therapeutic goal. This distinction is rarely reported in the exercise-ASD literature, where most studies evaluate outcomes in a single context (Liang et al., 2022; Rivera et al., 2025). The present data suggests that while the intervention is highly efficient at producing clinically meaningful change somewhere, achieving consistent cross-contextual transfer requires longer intervention duration, higher dose, or adjunctive strategies targeting home-context generalization.

Responder and Non-Responder Profiles

Among clinical responders, distinctive patterns were identified. School-improving responders showed the greatest gains in cognitive flexibility and emotional regulation, while home-based responders showed improvements in emotional regulation. Emotional regulation emerged as particularly sensitive to intervention, consistent with literature showing that physical exercise has positive effects on emotion regulation in children and adolescents (Liang et al., 2022).

Improvements in the Cognitive Regulation Index suggest that cognitive flexibility, working memory, and planning skills improve preferentially in structured environments such as school, which imposes explicit rules, sequential tasks, and constant demands for attentional change. Improvements in the Emotional Regulation Index at home coincide with literature linking family life to greater demands for emotional self-regulation due to unpredictability, affective intensity, and frequency of social interactions (Costescu et al., 2024; Mazefsky et al., 2013). Thus, exercise-induced emotional improvements could transfer more effectively to the family environment, possibly because the emotional demands of family contexts share regulatory features with the emotional demands of group physical activity (e.g., affective intensity, peer interaction).

The only participant who achieved clinically significant improvement in both settings presented a profile of balanced improvements in all three indices. This pattern supports integrative models of executive function that postulate contextual generalization requires coordinated improvements in behavioral, emotional, and cognitive regulation (Ameis et al., 2022).

On the other hand, 54.5% of experimental group participants did not reach the reliable clinical change threshold. Factors that could predict intervention response include baseline symptom severity, comorbidities (particularly ADHD), prior physical activity level, and family and contextual factors. Future studies should explore these potential moderators to better understand for whom the intervention works best.

The neurobiological mechanisms proposed in the literature to underlie exercise-induced cognitive effects include: (a) increased cerebral blood flow and prefrontal cortex activation; (b) release of neurotrophic factors such as BDNF; and (c) modulation of cortical excitation-inhibition systems through neurotransmitter systems including dopamine, serotonin, and norepinephrine (Basso & Suzuki, 2017; Liang et al., 2022). These mechanisms have been proposed as providing biological plausibility for the present findings, suggesting that physical exercise could, in principle, enhance the neural substrates underlying executive functions in ASD populations and potentially address the atypical frontocortical development documented in autism (Carper & Courchesne, 2005; Ong & Fan, 2023). However, it should be explicitly noted that these mechanisms have been established primarily in typically developing populations and in animal models; their applicability to children with ASD remains to be empirically demonstrated. Consequently, the mechanism-level interpretation offered here is intentionally tentative and should be regarded as a hypothesis to be tested by future neurophysiological studies in this population.

Clinical Implications

The implications for practice, offered with appropriate caution given the preliminary nature of the evidence, include: (a) the potential value of considering structured physical exercise programs as one component of Individualized Education Plans for children with Level 1 ASD, pending confirmation in adequately powered trials; (b) the importance of evaluating intervention effects in multiple naturalistic contexts, as informant discrepancies appear to be meaningful; and (c) the potential of multicomponent programs as a candidate complement to other non-pharmacological interventions, although this hypothesis has not yet been empirically confirmed (Liang et al., 2022; Rivera et al., 2025). The NNT of 2.20, while preliminary, suggests that, among those who respond, the intervention could be not only meaningful but also efficient from a clinical standpoint; however, given the non-significant between-group comparison and the limited statistical power, this estimate should not yet be used to justify implementation at the population level, although it is relevant to consider in the context of the limited resources available in many educational and clinical settings serving children with ASD.

Implications for Future Trial Design

The within-subject effect sizes detected in this pilot (d = 1.02 at school, d = 0.76 at home) provide a defensible basis for a priori power calculation of a subsequent confirmatory randomized controlled trial. Assuming a two-group design with $\alpha = .05$ and 80% power:

- Using the school-context effect (down-rounded to a defensible between-group estimate of d = 0.80), the future trial would require approximately n = 26 participants per group (52 total).
- Using the family-context effect ($d \approx 0.50$), approximately n = 64 per group (128 total) would be needed.

The substantially larger sample required to detect the family-context effect supports using school-context BRIEF-2 GEC as the primary outcome in the future trial, with family-context as a secondary outcome. These estimates should be adjusted for the design effect if the future trial uses cluster (group-based) delivery of the intervention (estimated ICC ≈ 0.05 for school-based physical activity programs).

G*Power v3.1 was used for these calculations (Faul et al., 2007).

Limitations

The present study has several limitations that should be considered when interpreting the results.

Limited sample size and statistical power: The sample of 18 participants with complete pre-post data is small for detecting small to medium-sized effects with adequate statistical power. The estimated power (~31%) explains the lack of statistical significance in Fisher's exact test despite clinically significant differences.

Quasi-experimental design without randomization: group assignment was based on logistical accessibility rather than on random allocation, which may have introduced selection bias related to unmeasured family, contextual, or motivational variables, and limits the internal validity of the between-group comparisons.

Informant dependence on outcome measurement. BRIEF-2 depends on parent and teacher reports, which may be subject to expectation biases and social desirability.

Limited generalizability: Participants were recruited from specific educational centers, which may limit generalizability to other Level 1 ASD populations with different socioeconomic or geographical characteristics.

Conclusions

The results of this pilot multiple case study provide preliminary evidence that a 12-week multicomponent physical exercise program could produce clinically meaningful improvements in executive functions in children with Level 1 ASD, particularly in the school context. The detected effect sizes (within-subject d = −1.02 at school, d = −0.76 at home; NNT = 2.20 for any response) are consistent with the magnitude of effects reported in the broader literature and offer a defensible basis for the a priori power calculation of a future confirmatory randomized controlled trial. However, given the non-significant between-group comparison of responder rates, the small sample size, and the quasi-experimental design, these findings should be interpreted as preliminary and hypothesis-generating. Definitive conclusions about the efficacy of the intervention await replication in adequately powered, randomized controlled trials.

Multicomponent physical exercise may represent an accessible, low-risk therapeutic option that could complement existing pharmacological and behavioral strategies to address the executive deficits that impact daily functioning of children with Level 1 ASD, although this hypothesis requires empirical confirmation.

Acknowledgements

The authors thank all the parents and teachers who participated by completing the documents. We also express our appreciation to the children and families involved in this multi-component physical activity program.

Financing

No funding was received for conducting this study.

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References

Ameis, S. H., Haltigan, J. D., Lyon, R. E., Sawyer, A., Mirenda, P., Kerns, C. M., Smith, I. M., Vaillancourt, T., Volden, J., Waddell, C., Zwaigenbaum, L., Bennett, T., Duku, E., Elsabbagh, M., Georgiades, S., Ungar, W. J., Zaidman-Zait, A., Lai, M.-C., Szatmari, P., & Pathways in ASD Study Team. (2022). Middle-childhood executive functioning mediates associations between early-childhood autism symptoms and adolescent mental health, academic and functional outcomes in autistic children. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *63*(5), 553–562. https://doi.org/10.1111/jcpp.13493

Basso, J. C., & Suzuki, W. A. (2017). The Effects of Acute Exercise on Mood, Cognition, Neurophysiology, and Neurochemical Pathways: A Review. *Brain Plasticity*, *2*(2), 127–152. https://doi.org/10.3233/BPL-160040

Blijd-Hoogewys, E. M. A., Bezemer, M. L., & van Geert, P. L. C. (2014). Executive functioning in children with ASD: An analysis of the BRIEF. *Journal of Autism and Developmental Disorders*, *44*(12), 3089–3100. https://doi.org/10.1007/s10803-014-2176-9

Carper, R. A., & Courchesne, E. (2005). Localized enlargement of the frontal cortex in early autism. *Biological Psychiatry*, *57*(2), 126–133. https://doi.org/10.1016/j.biopsych.2004.11.005

Citrome, L. (2008). Compelling or irrelevant? Using number needed to treat can help decide. *Acta Psychiatrica Scandinavica*, *117*(6), 412–419. https://doi.org/10.1111/j.1600-0447.2008.01194.x

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Lawrence Erlbaum Associates. https://doi.org/10.4324/9780203771587

Costescu, C., Adrian, R., & Carmen, D. (2024). Executive functions and emotion regulation in children with autism spectrum disorders. *European Journal of Special Needs Education*, *39*(3), 477–486. https://doi.org/10.1080/08856257.2023.2215010

Darretxe, L., & Sepúlveda, L. (2011). Educational Strategies to Address the Educational Needs of Students with Asperger Syndrome in the Mainstream Classroom. *Electronic Journal of Research in Educational Psychology*, *9*(2). https://doi.org/10.25115/ejrep.v9i24.1477

Deci, E. L., & Ryan, R. M. (2012). Self-Determination Theory. In P. Van Lange, A. Kruglanski, & E. Higgins, *Handbook of Theories of Social Psychology: Volume 1* (pp. 416–437). SAGE Publications Ltd. https://doi.org/10.4135/9781446249215.n21

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/bf03193146

Gentil-Gutiérrez, A., Santamaría-Peláez, M., Mínguez-Mínguez, L. A., Fernández-Solana, J., González-Bernal, J. J., González-Santos, J., & Obregón-Cuesta, A. I. (2022). Executive Functions in Children and Adolescents with Autism Spectrum Disorder in Family and School Environment. *International Journal of Environmental Research and Public Health*, *19*(13), 7834. https://doi.org/10.3390/ijerph19137834

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2015). *BRIEF-2: Behavior Rating Inventory of Executive Function (2nd ed.).* Psychological Assessment Resources. https://doi.org/10.1037/t79467-000

Gray, C. (2015). *The new social story book: Revised and expanded* (15th anniversary ed.). Future Horizons.

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience*, *9*(1), 58–65. https://doi.org/10.1038/nrn2298

Hou, Y., Wang, Y., Deng, J., & Song, X. (2024). Effects of different exercise interventions on executive function in children with autism spectrum disorder: A network meta-analysis. *Frontiers in Psychiatry*, *15*, 1440123. https://doi.org/10.3389/fpsyt.2024.1440123

Hunter, J. D. (2007). Matplotlib: A 2D Graphics Environment. *Computing in Science & Engineering*, *9*(3), 90–95. https://doi.org/10.1109/MCSE.2007.55

Jacobson, N. S., & Truax, P. (1991). Clinical significance: A statistical approach to defining meaningful change in psychotherapy research. *Journal of Consulting and Clinical Psychology*, *59*(1), 12–19. https://doi.org/10.1037//0022-006x.59.1.12

Kaloka, P. T., Nopembri, S., Yudanto, Y., & Elumalai, G. (2024). Improvement of Executive Function Through Cognitively Challenging Physical Activity with Nonlinear Pedagogy in Elementary Schools. *Retos*, *51*, 673–682. https://doi.org/10.47197/retos.v51.101024

Kenworthy, L. E., Black, D. O., Wallace, G. L., Ahluvalia, T., Wagner, A. E., & Sirian, L. M. (2005). Disorganization: The forgotten executive dysfunction in high-functioning autism (HFA) spectrum disorders. *Developmental Neuropsychology*, *28*(3), 809–827. https://doi.org/10.1207/s15326942dn2803_4

Kheirollahzadeh, M., Alizadeh Zarei, M., Amini, M., & Dehghan, F. (2021). The Relationship of School Participation with Motor Proficiency and Executive Function in Children with Autism Spectrum Disorder. *Iranian Journal of Child Neurology*, *15*(3), 65–76. https://doi.org/10.22037/ijcn.v15i2.19721

Koeppen, S. (1974). Relaxation training for children: A guide for therapists. *Elementary School Guidance and Counselling*, 14–20.

Kratochwill, T. R., Horner, R. H., Levin, J. R., Machalicek, W., Ferron, J., & Johnson, A. (2023). Single-case intervention research design standards: Additional proposed upgrades and future directions. *Journal of School Psychology*, *97*, 192–216. https://doi.org/10.1016/j.jsp.2022.12.002

Liang, X., Li, R., Wong, S. H. S., Sum, R. K. W., Wang, P., Yang, B., & Sit, C. H. P. (2022). The Effects of Exercise Interventions on Executive Functions in Children and Adolescents with Autism Spectrum Disorder: A Systematic Review and Meta-analysis. *Sports Medicine*, *52*(1), 75–88. https://doi.org/10.1007/s40279-021-01545-3

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., DiLavore, P. C., Pickles, A., & Rutter, M. (2000). The autism diagnostic observation schedule-generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders*, *30*(3), 205–223.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, *24*(5), 659–685. https://doi.org/10.1007/BF02172145

Maldonado, M., Fournier, M., Martinez, R., González, J., Espejo-Saavedra, J., & Santamaría, P. (2017). *BRIEF®-2. Evaluación Conductual de la Función Ejecutiva-2. Adaptación española*. Hogrefe TEA Ediciones. https://www.hogrefe-tea.com/public/catalogo/producto/brief-2-evaluacion-conductual-de-la-funcion-ejecutiva-2

Matson, J. L., & Boisjoli, J. A. (2009). The token economy for children with intellectual disability and/or autism: A review. *Research in Developmental Disabilities*, *30*(2), 240–248. https://doi.org/10.1016/j.ridd.2008.04.001

Mazefsky, C. A., Herrington, J., Siegel, M., Scarpa, A., Maddox, B. B., Scahill, L., & White, S. W. (2013). The role of emotion regulation in autism spectrum disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, *52*(7), 679–688. https://doi.org/10.1016/j.jaac.2013.05.006

McDonald, R. G., Cargill, M. I., Khawar, S., & Kang, E. (2024). Emotion dysregulation in autism: A meta-analysis. *Autism*, *28*(12), 2986–3001. https://doi.org/10.1177/13623613241257605

Mesibov, G., Shea, V., & Schopler, E. (2005). *The TEACCH approach to autism spectrum disorders.* Springer.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex 'Frontal Lobe' tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Morris, S. B. (2008). Estimating Effect Sizes from Pretest-Posttest-Control Group Designs. *Organizational Research Methods*, *11*(2), 364–386. https://doi.org/10.1177/1094428106291059

Ong, L. T., & Fan, S. W. D. (2023). Morphological and Functional Changes of Cerebral Cortex in Autism Spectrum Disorder. *Innovations in Clinical Neuroscience*, *20*(10–12), 40–47.

Ozonoff, S., Pennington, B., & Rogers, S. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry*, *32*(7), 1081–1105. https://doi.org/10.1111/j.1469-7610.1991.tb00351.x

Piaget, J. (1995). *La construcción de lo real en el niño*. Grijalbo. https://dialnet.unirioja.es/servlet/libro?codigo=230957

Rivera, R. A., Robertson, M. C., & McCleery, J. P. (2025). Exercise Interventions for Autistic People: An Integrative Review of Evidence from Clinical Trials. *Current Psychiatry Reports*, *27*(5), 286–306. https://doi.org/10.1007/s11920-025-01597-6

Robles, A., Gallegos-Abello, C., Ulloa-Campos, N., Cabrera-Castillo, M., Zapata-Lamana, R., Tapia, A., Reyes-Molina, D., Ortiz, C., & Cigarroa, I. (2023). Characteristics and effects of school based physical activity programs for schoolchildren with autism spectrum disorder: A scoping review. Retos, 49, 203–213. https://doi.org/10.47197/retos.v49.95002

Ryan, T., & Marshall, J. (2018). Pedagogical preparedness: Understanding executive functioning and high functioning autism. *Journal of Pedagogical Research*, *2*(2), 91–101.

Sadozai, A. K., Sun, C., Demetriou, E. A., Lampit, A., Munro, M., Perry, N., Boulton, K. A., & Guastella, A. J. (2024). Executive function in children with neurodevelopmental conditions: A systematic review and meta-analysis. *Nature Human Behaviour*, *8*(12), 2357–2366. https://doi.org/10.1038/s41562-024-02000-9

Schmidt, J. D., Luiselli, J. K., Rue, H., & Whalley, K. (2013). Graduated exposure and positive reinforcement to overcome setting and activity avoidance in an adolescent with autism. *Behavior Modification*, *37*(1), 128–142. https://doi.org/10.1177/0145445512456547

Suskind, R. (1998). *The whole child: A positive approach to young children with developmental challenges.*

Vallejos-Meriño, C., Gómez-Álvarez, N., & Campos-Campos, K. I. (2024). Impacto de la clase de Educación Física en escolares diagnosticados con Trastornos del Espectro Autista al interior de una Escuela Especial en Chile (Impact of the physical education class on schoolchildren diagnosed with Autism Spectrum Disorders in a Special School in Chile). *Retos*, *52*, 499–508. https://doi.org/10.47197/retos.v52.102286

Virues-Ortega, J., Julio, F. M., & Pastor-Barriuso, R. (2013). The TEACCH program for children and adults with autism: A meta-analysis of intervention studies. *Clinical Psychology Review*, *33*(8), 940–953. https://doi.org/10.1016/j.cpr.2013.07.005

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.

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