



REVIEW ARTICLE

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## The Impact of Physical Activity and Exercise Strategies on The Physical-Motor and Cognitive Treatment of Autism

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### Abstract

Autism Spectrum Disorder (ASD) involves lifelong impairments in social interaction, social functioning, and self-sufficiency. To analyze the impact of physical activity (PA) and physical exercise (PE) strategies on the physical-motor and cognitive treatment of individuals with autism. Databases searched included PubMed/MEDLINE, Web of Science, Latin American and Caribbean Health Sciences Literature (LILACS/BVS), SciELO, and Embase. The PRISMA 2020 guidelines were followed, and the risk of bias was assessed using the National Institutes of Health (2021). Nine studies were included in qualitative synthesis. Findings indicated that physical exercise should be performed at least twice per week for a minimum duration of two months to improve quality of life and motor functioning. Improvements in motor skills, adaptive behavior, social skills, and cognitive functioning were observed following the implementation of physical activity programs, particularly when integrated with play-based or game-oriented approaches in daily routines. Physical exercise programs also proved relevant, especially regarding the duration and frequency of implementation. Concerning mirroring activities in individuals with ASD, these do not directly enhance empathy but may improve self-reported well-being, social competence, and body awareness. Therefore, this review highlights the need for the development of structured protocols using mixed-methods (qualitative and quantitative) designs to better capture the emotional experiences and cognitive processing of individuals with ASD before quantification. Such integration can inform the design of evidence-based interventions tailored to the complex and diverse needs within the autism spectrum.

### Keywords

Learning, Autism Spectrum Disorder, Adaptation, Psychological, Cognition

## INTRODUCTION

Autism Spectrum Disorder (ASD), as defined by the [American Psychiatric Association \(2013\)](#), is characterized by difficulties in social interaction and communication, as well as by restricted and repetitive behaviors. It is a highly prevalent condition in childhood, with varying degrees of dependency (mild, moderate, or severe), according to the [Santa Catarina and Secretaria de Estado da Educação \(2018\)](#). In Brazil, it is estimated that more than five million individuals with ASD and their

families still do not receive adequate support ([Freire & Nogueira, 2023](#)).

Physical activity (PA), as part of daily routines, and physical exercise (PE), when prescribed, play an essential role in reducing social impairments and repetitive behaviors ([Wang et al., 2023](#)). However, sensory alterations present in ASD directly influence these difficulties, and the strategies adopted by professionals and family members often fail to consider the specific sensory needs of everyone ([Bitencourt et al., 2024](#)).

Despite the growing recognition of the benefits of PA and PE for managing ASD, studies

vary widely in their methodologies, intervention modalities, durations, and outcome measures, which limit comparability and weaken the consistency of findings (Bitencourt et al., 2024). Furthermore, few investigations have integrated motor, behavioral, and socioemotional outcomes within a single analytical framework, leaving a substantial research gap in understanding how these domains interact to promote holistic development in individuals with ASD. Therefore, previous reviews rarely combined motor, behavioral, and socioemotional outcomes. This review aims to fill that gap. Identifying the most complex aspects of social behavior in individuals with ASD may represent a key step toward improving their neuromotor and cognitive learning capacities (Nascimento et al., 2021).

Understanding the challenges faced by family members and their demands regarding individuals with ASD is essential to identifying their needs and providing adequate support for developing contemporary treatment strategies. Continuous and systematic analyses of key aspects underlying intervention proposals increase the likelihood programs centered on family and school context of achieving effective and socially meaningful outcomes (Gringas et al., 2017). In view of these limitations, this review is justified by the need to consolidate and systematize existing scientific evidence on the effects of PA and PE in individuals with ASD. By mapping methodological patterns and identifying inconsistencies across studies, this work aims to clarify which intervention modalities yield the most relevant outcomes.

Recent evidence indicates that structured PA and PE interventions promote benefits across motor, cognitive, behavioral, and socioemotional domains. A meta-analysis including 587 participants demonstrated a reduction in the core symptoms of ASD, such as social deficits and repetitive behaviors (Jia et al., 2024). Reviews involving children and adolescents have also reported improvements in motor skills, cognitive functions, social interaction, and behavior, although methodological heterogeneity remains high (Suárez-Manzano et al., 2024). In young adults, gains in physical fitness and quality of life have been observed; however, robust evidence regarding core symptoms and cognitive markers is still lacking (Okkenhaug et al., 2024).

Nevertheless, uncertainties persist regarding the most effective intervention modalities to

enhance sociability, communication, and functional autonomy. This scenario underscores the need for greater methodological rigor in the design of therapeutic strategies, as well as for active parental participation throughout the intervention process (Van Niekerk et al., 2023).

Despite recent advances, previous reviews present recurring limitations, such as high heterogeneity in experimental designs, variation in intervention duration and frequency, lack of standardization in outcome measures, and limited integration of motor, behavioral, and socioemotional indicators. There is also an underrepresentation of Latin American studies and those conducted in school settings, which restricts the cultural applicability of the results. Consequently, a gap remains in the integrated understanding of the effects of PA and PE on the overall development of individuals with ASD, particularly within inclusive and sociocultural diverse educational contexts.

The present review expands upon previous syntheses by adopting a broader methodological approach that encompasses international scientific databases and an age range extending from childhood through adolescence. By integrating motor, behavioral, and socioemotional dimensions, it consolidates evidence regarding the effects of physical activity and exercise in ASD, enabling the identification of more effective intervention patterns based on variables such as duration, frequency, intensity, and modality. In this regard, the articulation between motor performance and cognitive-behavioral development reinforces contemporary models of learning and neural plasticity, guiding culturally contextualized therapeutic and educational practices aimed at strengthening autonomy and quality of life. Understanding the link between motor performance and cognitive processes through physical exercise further strengthens models of learning and neural plasticity, while also informing more effective therapeutic and educational interventions that promote autonomy and social engagement (Nascimento et al., 2021; Singh et al., 2025).

Thus, ASD profoundly impacts the lives of affected children and their families, who in turn require specific knowledge for navigating everyday situations. For example, understanding operant behavior, defined as a process shaped by complex

interactions among political and educational factors, is essential not only for improving professional training and domain-specific expertise but also for enhancing responsiveness to the everyday needs of individuals with ASD (Nascimento et al., 2021; Rocha et al., 2024). Therefore, the objective of this study is to analyze the impact of PA and PE on ASD progression, emphasizing the interrelations among motor, behavioral, and socioemotional skills.

## MATERIALS AND METHODS

This systematic review was conducted in accordance with the methodological guidelines of PRISMA 2020 (Page et al., 2021) (see Supplementary Material S1, PRISMA 2020 Checklist). The review protocol was registered under CRD42024592261 in the Centre for Reviews and Dissemination and in the International Prospective Register of Systematic Reviews (PROSPERO). The meta-analysis was not performed due to the high methodological heterogeneity among the included studies and the categorical nature of the variables, which precluded direct comparison. Subsequent to the PROSPERO registration, three modifications were made: a more concise title was adopted; the EndNote X9.1 software (Clarivate Analytics) was replaced with the Rayyan Platform (Rayyan Systems Inc., Qatar) (Ouzzani et al., 2016); and the risk-of-bias scale described in the Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0) (Higgins & Green, 2011) We replaced from National Institutes of Health (2021).

### Eligibility Criteria

In the initial stages, a preliminary protocol was developed with criteria prioritizing studies published in English, Portuguese, and Spanish between January 2019 and June 2025. As methodological support, the search was conducted using the PICOS strategy (Santos et al., 2007).

**Inclusion Criteria:** Population (P): individuals diagnosed with ASD, aged 2 to 70 years, of both sexes. Intervention (I): studies in which physical exercise (planned, structured, repetitive) and/or physical activity (movements that increase energy expenditure above resting levels) were used as therapeutic approaches for ASD. Control (C): placebo-controlled or otherwise controlled clinical study designs with clear comparison between intervention and control conditions. Outcomes (O):

studies reporting therapeutic effects or measurable outcomes associated with PA or PE interventions in individuals with ASD. Study design (S): Clinical trials, randomized controlled trials, and crossover randomized controlled trials.

**Exclusion Criteria:** Population (P): Studies involving individuals without ASD, including those with neurological, orthopedic, or other conditions that may confound results. Intervention (I): Strategies that do not involve PA or PE or that are unrelated to therapeutic outcomes in ASD. Control (C): Studies lacking comparative analyses, without a control condition, or without pre- and post-intervention assessments. Outcomes (O): Studies that do not report relevant outcomes related to the effects of PA or PE. Study design (S): Reviews, observational studies, commentaries, informational pamphlets, newspapers, letters, opinions, editorials, and conference abstracts.

### Information Sources

The databases searched included Scopus, PubMed/MEDLINE, Latin American and Caribbean Health Sciences Literature (LILACS), Web of Science, SciELO, and Embase.

### Search Strategies

Descriptors were searched in March and April 2024 using Medical Subject Headings (MeSH). The reference lists of included studies were manually screened to identify additional eligible references.

The selected descriptors were *Learning* (Entry Terms: *Discrimination Learning*), *Autism Spectrum Disorder* (Entry Terms: *Autistic Spectrum Disorder*), *Adaptation, Psychological* (Entry Terms: *Psychological Recovery*), and *Cognition* (Entry Terms: *Cognitive Function* or *Insight*) and (Entry Terms: *Physical Activity*). These were combined using the Boolean operators AND and OR (Table 1). The distribution of database searches is summarized in Supplementary Material S2).

### Selection Process

Data extraction procedures were conducted according to a predefined protocol that established standardized parameters for data collection and ensured comparability among the included studies, particularly regarding sample size, study design, and intervention characteristics.

The extracted variables included: author, year, and country; inclusion and exclusion criteria; study type (RCT, CRCT, CT); total and group-specific sample size, with sex distribution; intervention period and session duration; and

characteristics of both the intervention and control groups. To ensure sample comparability and address heterogeneity across studies, the predefined protocol established eligibility thresholds (a minimum of 10 participants per group), the distinction between randomized controlled trials and nonrandomized controlled trials, and rules for harmonizing data on session duration and frequency. In studies that did not clearly report the intervention period (minimum of 4 weeks) or the number of sessions (minimum of 8 sessions),

surrogate parameters were applied based on the mean values observed in included studies with similar characteristics.

Although no publication year restriction was applied, preference was given to more recent studies providing stronger scientific evidence and higher internal validity. Study selection and data interpretation followed the recommendations of the Centre for Evidence-Based Medicine (University of Oxford, UK), consistent with the established evidence hierarchy (Murad et al., 2016).

**Table 1.** Descriptors used for the search, according to medical subject headings

Search terms	Descriptors The combination of MeSH
Learning	“Learning” OR “ <u>Discrimination Learning</u> ”
Autism Spectrum Disorder	“Autism Spectrum Disorder” OR “Disorder, Autistic Spectrum”
Adaptation, Psychological	“Adaptation, Psychological” OR “Recovery, Psychological”
Cognitive	“Cognitive” OR “Cognitive Function” OR “Insight”
Physical Activity	“Physical Activity” OR “Exercise, Physical”
Combination	#1 AND # 2 AND # 3 AND # 4 AND # 5

### Data Collection and Listing Process

Electronic searches were conducted independently by two researchers (J.S. and R.F.). Search results from the electronic databases were exported in compatible formats and imported into the Rayyan platform (Rayyan Systems Inc., Qatar) for blinded and independent screening by reviewers (Ouzzani et al., 2016).

A standardized extraction form was created for the selected studies based on the predefined eligibility criteria. Three stages were performed: title screening, abstract screening, and full-text review. Studies meeting the inclusion criteria were jointly agreed upon by both reviewers; in cases of disagreement, a third evaluator (I.B.N.) resolved the conflict.

The review was guided by the following research question: What is the impact of PA and PE strategies involving physical-motor and cognitive stimulation that lead to greater improvements in individuals with ASD?

Subsequently, a reference selection process was established comprising the following steps: identification of studies through database searches, analysis of populations, methods, and data related to techniques applied to participants, and evaluation of outcomes including anthropometric parameters and systematic data. The following information was extracted from each included study: (1) Study characteristics (author, year of publication, and

country); (2) Inclusion and exclusion criteria; (3) Study design; (4) Sample size and sex of participants; (5) Period and duration of the intervention.

Additionally, another table was compiled summarizing the authors, publication years, and detailed descriptions of the intervention strategies. three main themes were explored in the discussion section to facilitate alignment with the objectives of this review:

- Evolution and transformation of Research on Physical Activity and ASD;
- Effects of different therapeutic intervention modalities in individuals with ASD;
- Benefits of physical activity in the social and behavioral development of individuals with ASD.

### Risk of Bias Assessment in Selected Studies

The quality of the included studies was assessed using two tools contained in the Quality Assessment of Controlled Intervention Studies (Randomized Clinical Trial) of the (National Institutes of Health, 2021). The tool requires that certain criteria are met by the studies, and at the end of the evaluation, a score is assigned according to each criterion answered. For a "yes" answer, one point is added. For the answers "no", "not applicable", "not reported", or "cannot be determined", the value assigned is considered zero. The tool performs an evaluation based on 14

criteria, ranging from zero to 14 points. The result was calculated by adding the scores of all criteria (National Institutes of Health, 2021). Previous studies have used this evaluation strategy and demonstrated satisfactory applicability (Hayes et al., 2018; Sarkies et al., 2017).

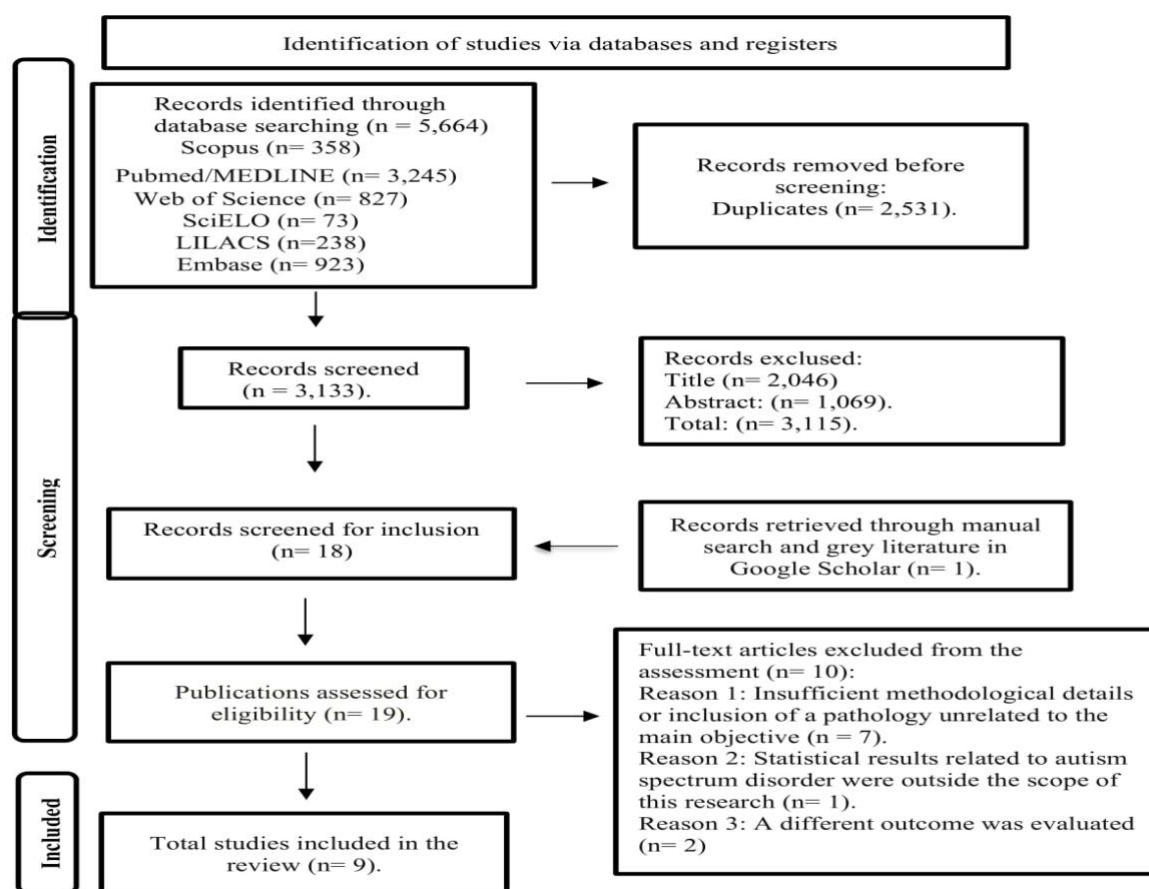
The degree of agreement between the two evaluators was measured using Cohen's Kappa test. For interpretation, the approach, of Mchugh (2012) was used, which classifies agreement as: no (0-4%); minimum (4-15%); weak (15-35%); moderate (35-63%); strong (64-81%); and near perfect (82-100%). Inter-rater reliability was assessed using Cohen's Kappa. observer agreement for all items was 95.71%.

## RESULTS

### Study Selection

Across all selected databases, 5,664 records related to the topic of interest were initially identified. After removing 2,531 duplicates, 3,133 records remained for screening. A comprehensive review of titles and abstracts excluded 3,115 records. One additional study was retrieved from the gray literature (Google Scholar), resulting in 19 eligible articles.

During the full-text assessment, nine articles were excluded for the following reasons: seven lacked sufficient methodological detail or included pathologies unrelated to the primary objective, one presented statistical result beyond the scope of this review, and two addressed different outcomes. Consequently, nine studies were included in the qualitative synthesis (Figure 1).



**Figure 1** - Flowchart of the selection process for the literature search. Florianópolis, SC, Brazil, 2023.

Source: Checklist de Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA statement 2020: an updated guideline for reporting systematic reviews. *BMJ* 2021; 372:71. Doi: 10.1136/bmj. n71. For more information, visit: <http://www.prisma-statement.org/>.

### Study Characteristics

#### General Characteristics by Study Type and Country of Origin

After applying the selection criteria, this systematic review included seven randomized

controlled trials (RCTs), one clinical trial (CT), and one crossover randomized controlled trial (CRCT). Regarding the geographical distribution, the studies were conducted in diverse regions: Brazil (n = 2; 22.2%), Spain (n = 1; 11.1%), Iran (n = 1; 11.1%),

Australia (n = 1; 11.1%), Germany (n = 1; 11.1%), the United States (n = 1; 11.1%), South Korea (n = 1; 11.1%), and China (n = 1; 11.1%). Details are presented in Table 2.

**Table 2.** General characteristics of the studies according to type and country of development

Author / Year / Country	IC / EC	Study Type	n / Sex	Session Period and Duration
Barrios-Fernández et al. (2022) / Spain	IC: 6–17 years, cerebral palsy/developmental neurodisability, informed consent form (ICF), fluent in English, cognitively capable of following the exercise program. EC: Failure to meet any inclusion criteria.	RCT	52 (EG: 26; CG: 26) / M & F	Nine weeks, twice per week.
Dehghani et al. (2023) / Iran	IC: ASD, 7–11 years, ICF. EC: Asperger’s, pervasive developmental disorder, neuromotor disorders, or injuries within the past year.	RCT	24 (EG: 12; CG: 12) / M & F	Eight weeks, three times per week, 45-minute sessions.
Fears et al. (2023) / United States	IC: ASD, 6–44 years, nonverbal IQ > 70, ICF. EC: Comorbid genetic/neurological disorders, seizures, brain injury, structural abnormalities, attention problems, prior concussion, coordination issues, or medications affecting motor function; CG with SCQ < 8.	CT	35 (EG: 19; CG: 16) / M & F	Not reported; once per week.
Johnson et al. (2020) / Australia	IC: 2–17 years, ASD, ICF, sleep problems > three months, sleep < six hours/night. EC: Other sleep disorders, prohibited medications, melatonin use within two weeks before screening, allergy to melatonin/lactose, recent participation in clinical trials, sexually active adolescent females using contraceptives, pregnant, or breastfeeding.	RCT	47 (EG: 24; CG: 23) / M & F	Eight weeks; duration not specified.
Mastrominico et al. (2018) / Germany	IC: 14–52 years, native German speakers, ASD, ICF. EC: Absence of ICF; acute or transient psychotic disorders, IQ < 70, neurological diseases, or concurrent therapies during the study period.	RCT	57 (EG: 35; CG: 22) / M & F	Ten weeks, once per week.
Moraes et al. (2020) / Brazil	IC: Individuals aged 7–15 years with ASD in grades 1–5 of elementary school, mild or moderate autism diagnosed by a pediatric neurologist, assessed via patient history and psychological, communicative, and psychiatric evaluations. EC: Participants unable to understand the task (after three demonstrated attempts by the evaluator).	CRCT	100 (EG: 50; CG: 50) / M & F	Not reported; once per week, 60-minute sessions.
Nekar et al. (2022) / South Korea	IC: Children/adolescents aged 6–18 years with ASD, ability to see, hear, and follow basic instructions, literate in Korean. EC: Genetic syndromes (e.g., Fragile X), severe behavioral issues, sensory impairments, or inability to follow instructor’s guidance.	RCT	24 (EG: 12; CG: 12) / M & F	Four weeks, twice per week, 60-minute sessions.
Toscano et al. (2018) / Brazil	IC: ASD diagnosis in children aged 6–12 years established by a psychiatrist based on DSM-IV criteria. EC: Not reported.	RCT	44 (EG: 26; CG: 18) / M & F	Forty-eight weeks, twice per week, 40-minute sessions.
Zhao et al. (2021) / China	IC: DSM-5 criteria for F84 and signed ICF. EC: Participant withdrawal or fear of horses.	RCT	61 (EG: 31; CG: 30) / M & F	Sixteen weeks, twice per week, 60-minute sessions.

**Abbreviations:** IC – Inclusion Criteria; EC – Exclusion Criteria; CT – Clinical Trial; RCT – Randomized Controlled Trial; CRCT – Crossover Randomized Controlled Trial; CG – Control Group; EG – Experimental Group; CP – Cerebral Palsy; IQ – Intelligence Quotient; ICF – Informed Consent Form; ASD – Autism Spectrum Disorder; F – Female; M – Male; DSM-IV - Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition; F84 - Pervasive Developmental Disorders (PDD) in ICD-10 – International Classification of Diseases, 10th Revision; DMS-5 - Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition.

**Specified Strategies and Techniques**

The studies included in the qualitative synthesis employed a range of intervention

strategies and techniques tailored to the specific needs of individuals with ASD, as summarized in Table 3.

**Table 3.** Specified strategies and techniques, including the particularities of the studies included in the qualitative analysis

Author / Year / Country	Strategies Used
Barrios-Fernández et al. (2022) / Spain	This study analyzed the effects of the SSE on motor, sensory, and cognitive skills. The EG and CG were assessed at three time points: baseline, post-intervention, and one month after program completion. The protocol involved performing patterned movements on a mat to strengthen the lower limbs. The tools used included the SSP2 (child version), FACES, EFECO-S, and ENFEN for executive function assessment, and MACB-2 for balance and behavioral evaluation.
Dehghani et al. (2023) / Iran	This study assessed the effects of a multimodal exercise program on ground reaction force and plantar pressure during walking in boys aged seven to eleven years diagnosed with ASD using the GARS-2. The EG participated in SPARK sessions three times per week for forty-five minutes over eight weeks, while the CG continued with their usual care. A priori power analysis was performed using G*Power (n = 24), and training effects were analyzed using ANOVA.
Fears et al. (2023) / United States	Participants aged four to seventeen years included individuals with ASD (EG) and neurotypical individuals (CG). ASD diagnoses were confirmed using the ADOS-2 and ADI-R, while neurotypical participants met the criteria of IQ $\geq$ 70 (WASI-2) and SCQ < 8. Participants interacted with the Zeno R30 robot while wearing fitted reflective clothing for 3D motion capture using sixteen cameras, assessing nine degrees of freedom in the upper limbs. Following commands, they performed five repetitions of unimanual and bimanual movements imitating the robot's gestures (e.g., "Clap," "Celebrate," "Hug").
Johnson et al. (2020) / Australia	This study involved children and adolescents aged six to seventeen years who participated in a home-based exercise program. Specific goals were established using the COPM during the initial interview. The EG followed an eight-week program with instructional videos provided via Physitrack (website or app), while the CG received conventional paper-based instructions.
Mastrominico et al. (2018) / Germany	The study included six therapeutic groups across three institutions, with five to ten participants per group. Participants completed a pre-test consisting of questionnaires and diagnostic measures, including the SANS scale. The EG received weekly sixty-minute DMT sessions, while the CG was placed on a waiting list. After ten sessions, the EG completed a post-test using the same instruments plus additional items evaluating perceived therapeutic effects.
Moraes et al. (2020) / Brazil	The motor learning protocol was structured into blocks of five trials, including twenty acquisition trials, five retention trials (after five minutes), and five transfer trials using a touchscreen interface simulating falling bubbles within five seconds. Three interfaces were used: (a) Kinect (virtual environment), (b) keyboard (physical interaction), and (c) touchscreen (everyday familiarity). Participants, divided into ASD and typically developing (TD) groups, followed two task sequences, with the transfer phase always performed using the touchscreen interface.
Nekar et al. (2022) / South Korea	Twenty-four participants were randomly allocated to the EG and CG. A pre-test was conducted to evaluate repetitive behaviors, task accuracy, and reaction time. Developmental variables were measured before and after a four-week intervention consisting of fifteen-minute sessions twice a week. The EG performed cognitive-motor training using the UINCARE device, which integrates upper-, trunk-, and lower-limb motor exercises with cognitive tasks targeting attention, memory, calculation, and planning.
Toscano et al. (2018) / Brazil	The EG participated in a forty-eight-week physical activity program consisting of ninety-six sessions of forty minutes each, held twice a week. Sessions included a five-minute warm-up, a thirty-minute development phase with strength, balance, and coordination exercises, and a five-minute cool-down. The CG received regular care at a pediatric center specializing in ASD but did not participate in exercise sessions, maintaining their usual PA levels.
Zhao et al. (2021) / China	This study evaluated the effectiveness of a sixteen-week THR program for children with ASD, using EG and CG designs. Assessments were performed at three time points: pre-test (one week before), mid-test (eighth week), and post-test (after sixteen weeks), focusing on social skill development. The THR group participated in thirty-two sessions of sixty minutes each, structured to meet individual therapeutic goals addressing social skills, communication, and equestrian control. Teachers completed the SSIS-R to assess social behavior, while parents evaluated social interactions using the ABLLS-R.

**Abbreviations:** EG – Experimental Group; CG – Control Group; ASD – Autism Spectrum Disorder; SSP2 – Short Sensory Profile 2; MACB-2 – Movement Assessment Battery for Children, 2nd Edition; FACES – Perception of Differences Test; EFECO-S – Executive Functioning Questionnaire; ENFEN – Neuropsychological Assessment of Executive Functions Battery for Children (Spanish acronym); SSE – Square-Stepping Exercise; TST – total sleep time; SL – sleep latency; GARS-2 – Gilliam Autism Rating Scale, 2nd Edition; ADOS-2 – Autism Diagnostic Observation Schedule, 2nd Edition; ADI-R – Autism Diagnostic Interview – Revised; WASI-2 – Wechsler Abbreviated Scale of Intelligence, 2nd Edition; SCQ – Social Communication Questionnaire; COPM – Canadian Occupational Performance Measure; DMT – Dance Movement Therapy; THR – Therapeutic Horseback Riding Program; ABLLS-R – Assessment of Basic Language and Learning Skills – Revised; SSIS-R – Social Skills Improvement System Rating Scales; TD – Typical Development. Source: Authors (2024).

**Cochrane Risk-of-Bias (National Institutes of Health, 2021) Scores**

Two studies achieved a good rating (Dehghani et al. (2023) with a score of 13/14 and Nekar et al. (2022) with 11/14. The remaining seven studies were classified as fair, with total scores

ranging from 8 to 10 points: Barrios-Fernández et al. (2022) scored 8, Fears et al. (2023) scored 9, Johnson et al. (2020) scored 10, Mastrominico et al. (2018) scored 8, Moraes et al. (2020) scored 9, Toscano et al. (2018) scored 8, and Zhao et al. (2021) scored 8.

**Table 4.** Quality Assessment of Controlled Intervention Studies (Randomized Clinical Trial) National Institutes of Health” – (National Institutes of Health, 2021).

ID Studies	Criteria														Total Score	Quality rating
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
Barrios-Fernández et al. (2022)	1	1	0	0	1	1	0	1	0	0	1	1	1	1	8	Fair
Dehghani et al. (2023)	1	1	1	1	1	1	1	1	1	1	1	1	1	0	13	Good
Fears et al. (2023)	1	0	0	0	0	1	1	1	1	1	1	0	1	1	9	Fair
Johnson et al. (2020)	1	1	1	0	1	1	1	1	0	1	1	0	1	0	10	Fair
Mastrominico et al. (2018)	1	0	0	0	0	1	1	1	0	1	1	0	1	1	8	Fair
Moraes et al. (2020)	1	1	0	0	0	1	1	1	1	1	1	0	1	0	9	Fair
Nekar et al. (2022)	1	1	1	0	0	1	1	1	1	1	1	0	1	1	11	Good
Toscano et al. (2018)	1	0	0	0	1	1	1	0	0	1	1	1	1	0	8	Fair
Zhao et al. (2021)	1	1	0	0	0	1	1	1	0	0	1	0	1	1	8	Fair
<b>Agreement % (Kappa)</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>80</b>	<b>100</b>	<b>90</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>70</b>	<b>100</b>	<b>100</b>	<b>95,71</b>	
Kappa interpretation (agreement)	Alm ost perfe ct	Alm ost perfe ct	Alm ost perfe ct	Alm ost perfe ct	Str on g	Alm ost perfe ct	Alm ost perfe ct	Alm ost perfe ct	Alm ost perfe ct	Alm ost perfe ct	Alm ost perfe ct	Str on g	Alm ost perfe ct	Alm ost perfe ct		Almost perfect

**Abbreviations:** not applicable or not reported (zero); Yes (one). The quality of the studies was classified as poor (zero to four out of fourteen items), fair (five to ten out of fourteen items), or good (eleven to fourteen out of fourteen items).

Assessment criteria: 1. Was the study described as randomized, a randomized clinical trial, a randomized controlled trial, or an RCT? 2. Was the method of randomization appropriate (that is, use of a randomly generated allocation sequence)? 3. Was the treatment allocation concealed (so that allocations could not be predicted)? 4. Were the participants and study personnel blinded to the group assignments? 5. Were the outcome assessors blinded to the participants’ group allocation? 6. Were the groups similar at baseline in characteristics that could affect outcomes (e.g., demographics, risk factors, comorbidities)? 7. Was the overall attrition rate at

the outcome assessment twenty percent or less of the number allocated to treatment? 8. Was the differential attrition (between treatment groups) at the outcome assessment fifteen percentage points or less? 9. Was adherence to the intervention protocols high for each treatment group? 10. Were co-interventions avoided or similar across groups (e.g., similar background treatments)? 11. Were outcomes assessed using valid and reliable measures, applied consistently across all study participants? 12. Did the authors report that the sample size was sufficiently large to detect a Inter-rater reliability was excellent, with percent agreement ranging from 70% to 100% across items

and an overall agreement of 95.71%, corresponding to an “almost perfect” level of concordance according to the Kappa interpretation (table 4).

## DISCUSSION

### *Evolution and Transformation of Research on Physical Activity and ASD*

Since the first investigations in the 1990s, research on the relationship between PA, PE, and ASD predominantly focused on reducing stereotyped behaviors and improving basic motor skills, reflecting an initial and fragmented understanding of the underlying mechanisms (Levinson & Reid, 1993; Watters & Watters, 1980). In the early 2000s, with the advancement of sensorimotor integration models and inclusive educational approaches, studies began to consider cognitive, social, and emotional dimensions as equally relevant outcomes, situating physical activity within broader behavioral and pedagogical frameworks (Bremer et al., 2016; Lang et al., 2010).

In parallel, the field evolved methodologically. The incorporation of randomized controlled trials and the introduction of validated neurocognitive and behavioral measures enhanced the robustness of the evidence and enabled more integrated analyses across motor, affective, and social domains (Sowa & Meulenbroek, 2012; Zadok et al., 2022). This methodological sophistication also allowed for a more precise mapping of the effects of PA and PE on variables related to neural plasticity, motor learning, and adaptive social interaction.

Regarding intervention modalities, a progressive transition has been observed from aerobic, aquatic, or task-specific structured protocols to multimodal approaches based on cooperative games, playful activities, and family- and school-centered programs (Pan et al., 2022; Suárez-Manzano et al., 2024). This trend reflects the advancement of inclusive therapeutic practices that recognize the role of the social environment and parental support in strengthening autonomy and emotional self-regulation among individuals with ASD. Another study highlights the importance of both individual and group interventions, particularly those targeting communication deficits. Furthermore, additional studies are needed to assess the extent to which the effects of exercise vary according to the severity of ASD symptoms (Sowa & Meulenbroek, 2012).

### *Effects of different Exercise Program approaches in individuals with ASD*

In recent years, systematic reviews and meta-analyses (2021–2025) have reinforced the relevance of exercise-based interventions for managing ASD, consistently demonstrating positive effects on repetitive behaviors, social skills, and motor functions (Jia et al., 2024; Yang & Li, 2025). At the same time, interactive technologies such as exergaming, virtual reality (VR), and robotics have emerged as complementary strategies that combine physical movement, cognitive stimulation, and playful engagement (Carneiro et al., 2024; Graham et al., 2022; Kou et al., 2024).

Recent review studies (past three years) have demonstrated that physical exercise acts as a modulator of neurocognitive mechanisms in individuals with ASD. Regular engagement in aerobic and neuromotor activities stimulates the expression of neurotrophins, particularly brain-derived neurotrophic factor (BDNF), promoting synaptogenesis and the reorganization of cortical networks (prefrontal and hippocampal circuits) (Laguna et al., 2025). These findings suggest that movement-based therapies can modulate neuronal connectivity, fostering both functional and structural plasticity (Revelo Herrera et al., 2024). Such neuroplastic modulation directly affects executive functions, including response inhibition, cognitive flexibility, and working memory. The activation of these networks, as observed in neuroimaging studies and meta-analyses, reinforces the hypothesis that exercise not only enhances behavioral performance but also reconfigures the brain circuits underlying cognition and self-regulation (Suárez-Manzano et al., 2024).

Moreover, meta-analyses indicate that structured interventions combining coordinative, aerobic, and sensorimotor components result in improved sensory integration and postural control, with a positive impact on communication and social adaptation in individuals with ASD (Li & Zhang, 2025). Evidence also shows that exercise programs lasting at least eight weeks produce significant gains in balance and executive performance (Li & Zhang, 2025). Modalities that integrate multiple sensory systems, such as ball sports, martial arts, and rhythmic games, have proven particularly effective because they simultaneously engage attention, perception, and movement, thereby promoting integration among somatosensory,

vestibular, and executive systems. Collectively, these findings strengthen the theoretical rationale that exercise functions as a multimodal neuroplastic intervention capable of synchronizing motor and cognitive development, reducing stereotypies, and enhancing adaptive and social capacities in individuals with ASD (Kou et al., 2024; Singh et al., 2025).

Recent evidence indicates that VR-based interventions can promote cognitive and social improvements (Li et al., 2023; Yang et al., 2025), while robot-assisted therapies show potential for enhancing social and behavioral interactions, though more standardized and rigorous studies are still needed (Alabdulkareem et al., 2022). Collectively, these reviews highlight the growing development of exercise- and technology-based approaches for ASD, while revealing important methodological gaps related to protocol standardization and long-term outcome assessment, issues that the present review seeks to address by integrating and updating the most recent evidence on the topic.

Early research on the roles of PA and PE in autism, conducted prior to 2010, laid the groundwork for understanding how structured movement could influence behavioral and cognitive outcomes in individuals with ASD. Some of the first controlled studies, such as those by Todd and Reid (2006) and Pan (2010), demonstrated that swimming, jogging, and trampoline-based activities improved attention, social engagement, and reduced stereotyped behaviors. Likewise, research by Elliott et al. (1994) and Rosenthal-Malek and Mitchell (1997) showed that short bouts of aerobic exercise decreased self-stimulatory behaviors and increased task engagement in children with autism. These pioneering studies established the theoretical and empirical foundation for subsequent interventions, highlighting the potential of exercise as an effective non-pharmacological strategy to enhance both motor coordination and adaptive behavior.

Building on this foundational evidence, more recent systematic reviews and meta-analyses (2021–2025) have further corroborated the effectiveness of exercise-based interventions in ASD management, consistently showing positive effects on repetitive behaviors, social functioning, and motor performance (Jia et al., 2024; Yang & Li, 2025).

Scientific evidence also supports the effectiveness of therapeutic horseback riding (THR) as a complementary approach in children with ASD. In a randomized controlled trial, Zhao et al. (2021) evaluated the effects of a 16-week THR program on social interaction, reporting significant improvements in social skills in the experimental group (EG) compared to the control group (CG), both in the overall analysis and in the time  $\times$  group interaction. Continuous improvements in social skills over time were also observed. Significant effects were identified in communication, with notable gains in items such as “says thank you,” “makes eye contact when speaking,” and “says please”. The EG also exhibited progress in responsibility and self-control.

In behavioral assessments using the MACB-2 ( $\alpha \geq 0.90$ ), Barrios-Fernández et al. (2022) reported significant improvements in sensory, motor, and cognitive abilities following nine weeks of intervention in individuals with ASD. Outcomes also demonstrated enhancements in quality of life associated with motor actions such as walking, balancing, and jumping. Other researchers observed positive effects on emotional empathy, and empathetic concern. However, drawing conclusive results remains difficult due to the heterogeneity of symptoms and their varied manifestations among individuals with ASD (Mastrominico et al., 2018).

In a robot-assisted intervention comparing individuals with ASD and neurotypical participants, significant differences were observed in the following kinematic parameters: bounce (elbow flexion), give (shoulder abduction/adduction), wave (elbow flexion/extension), celebrate (shoulder flexion/extension), hug (shoulder abduction/adduction). Among neurotypical individuals, differences were identified in give (shoulder rotation), celebrate (elbow flexion/extension), and hug (shoulder rotation). These results highlight fundamental kinematic differences between groups, suggesting a strong association between motor performance and social communication abilities (Fears et al., 2023).

Overall, 16-week THR interventions and structured exercise-based programs demonstrated meaningful benefits in social skills, weight control, metabolic profile, ASD symptom reduction, and parent-reported quality of life in children with ASD (Dehghani et al., 2023).

Over a longer period of 48 weeks, multilevel ordinal modeling of exercise-based intervention

revealed changes in eight autistic traits, adjusted for ASD severity, gender, medication use, age range, and socioeconomic status. The overlap of the 95% confidence intervals (CIs) at baseline suggests initial variation between the intervention and control groups regarding social interaction, motor stereotypies, and sleep disturbances (Zadok et al., 2022).

Similarly, dance movement therapy (DMT) has been associated with enhanced empathy in adults with ASD. Results demonstrated significant effects on emotional empathy, mirroring, and empathic concern over time and in the time  $\times$  group interaction. The study suggests that participant mirroring alone may not directly foster empathy, emphasizing the importance of exploring interpersonal dynamics in promoting empathy, well-being, body awareness, and social competence (Mastrominico et al., 2018).

Tasks performed in virtual environments (VEs) appear to be effective and engaging tools that complement therapeutic approaches. VE-based interventions demonstrate strong potential for individuals with ASD. Although task execution in virtual settings can be more challenging, these interventions have been shown to result in significant improvements in real-world performance. Such findings support the transfer of motor and cognitive skills practiced in virtual contexts to everyday situations, positively contributing to the development of both domains (Moraes et al., 2020).

A study evaluating the multimodal exercise program “Sports, Play, and Active Recreation for Kids (SPARK)” assessed ground reaction forces and plantar pressure during walking in boys with ASD. Significant group  $\times$  time interactions were observed for the first peak of vertical ground reaction force, loading rate, and peak pressure in the medial heel region. Post hoc analyses confirmed significant reductions in the first peak of vertical ground reaction force, loading rate and medial heel peak pressure, supporting the program’s efficacy in improving biomechanical parameters during walking (Dehghani et al., 2023).

Regarding sleep quality, both pharmacological and non-pharmacological approaches yielded positive effects. Gringras et al. (2017), through a pharmacological trial, and Nekar et al. (2022), integrating yoga and cognitive-behavioral therapy (CBT), reported reductions in

sleep disturbances and improvements in emotional communication.

In cases where behavioral interventions alone were insufficient, the use of pediatric prolonged-release melatonin mini-tablets (PedPRM) significantly improved sleep. After 13 weeks, participants using PedPRM slept an average of 57.5 minutes longer per night, compared with 9.14 minutes for the placebo group (adjusted mean treatment difference: PedPRM–placebo =  $-32.43$  minutes;  $p = 0.034$ ). Sleep latency decreased by 39.6 minutes in the PedPRM group versus 12.5 minutes with placebo (adjusted mean difference =  $-25.30$  minutes;  $p = 0.011$ ), without causing earlier awakenings (Gringras et al., 2017).

Findings from Nekar et al. (2022) further indicated that integrating yoga with CBT can enhance self-regulation in children with ASD, leading to improved emotional control, a significant reduction in sleep problems, and enhanced emotional communication. ANOVA results revealed statistically significant improvements in stereotyped, compulsive, sameness, and restricted behaviors in the EG, whereas in the CG, improvements were limited to compulsive and restricted behaviors. No significant time  $\times$  group interaction was observed for repetitive behavior subscales.

In terms of cognitive functions, the EG showed significant improvements in working memory, cognitive flexibility, and cognitive inhibition, while the CG demonstrated gains in working memory and cognitive flexibility. Significant group interactions were observed in cognitive flexibility and response accuracy, with greater advancement in the EG. These results emphasize that PA programs should be individualized and adapted to the specific needs of individuals with ASD.

### ***Benefits of Physical Activity in the Social and Behavioral Development of Individuals with ASD***

ASD is characterized by persistent challenges in social interaction, communication, and repetitive behaviors, prompting the search for interventions that foster social and behavioral development. Consequently, several studies have investigated the effects of PA in this context.

Engagement in daily physical activities has been shown to significantly enhance social communication among individuals with ASD, demonstrating a positive effect on social communication disorder. Early interventions,

multicomponent exercise programs of moderate duration, moderate-to-high frequency, and long duration have demonstrated greater efficacy. Moreover, the type of PA selected plays a crucial role in participant adherence and may significantly influence social and behavioral interactions in individuals with ASD (Toscano et al., 2018).

Parental support is also fundamental for enhancing fundamental motor skills (FMS) among autistic individuals by encouraging participation in daily PA, whether in-person or online, provided that such interventions target FMS development and acquisition. This approach is particularly important for preventing declines in overall PA levels (Prieto et al., 2023). Furthermore, earlier findings revealed the significant influence of family involvement on the self-care abilities of children with ASD, underscoring the role of self-awareness in maintaining PA as part of daily routines (Sorensen & Zarrett, 2014).

Another relevant aspect involves sleep quality in children with mild ASD. Higher levels of daily physical activity are associated with an increased likelihood of longer sleep duration in this group. However, these benefits are not consistently observed among children with intellectual disabilities or severe ASD, underscoring the need for interventions tailored to the specific functional profiles of autistic children (Schmidt et al., 2024).

Interactive games can be successfully integrated into the daily routines of individuals with ASD, as motor training has demonstrated positive effects on restricted and repetitive behaviors, as well as improvements in executive functions. Augmented Reality (AR) games, when employed as cognitive-motor training strategies, have produced significant improvements in stereotyped, compulsive, severe, and restrictive behaviors, along with enhancements in working memory, cognitive flexibility, cognitive rigidity, and attention following four weeks of intervention.

When comparing the EG and the CG, the EG exhibited significant improvements in working memory, cognitive flexibility, and cognitive alterations, with statistically significant effects on stereotyped, compulsive, and restrictive behaviors. In the CG, significant improvements were observed only in compulsive and restrictive behaviors (Johnson et al., 2020).

Other studies further emphasize the importance of organizing PA interventions for individuals with ASD, as they contribute to

improvements in both executive and motor functions (Milajerdi et al., 2021). Nevertheless, determining the most effective game-based strategies for optimizing outcomes in children with ASD remains a continuing challenge for contemporary research.

Thus, both PA and PE act as biological (neuroplasticity), cognitive (executive function), and sensory (sensory integration) mediators; however, their impact depends on cultural context and local opportunities. In Asia, research is the most advanced, employing neuroimaging and rigorous protocols, typically supported by strong institutional frameworks (Deng et al., 2023; Li & Zhang, 2025). In Latin America, creative and inclusive approaches are adopted, focusing on accessibility and family participation (Figari & Fernández, 2023; Luelmo & Kasari, 2021). In Africa, despite the scarcity of resources and formal evidence, there is considerable cultural and environmental potential for community-based and ecologically grounded interventions addressing ASD care (Van et al., 2023). In Europe, studies have focused both on family dynamics and the caregivers' experiences (Herrero et al., 2024; Sánchez Amate & Luque de la Rosa, 2024). Socioeconomic factors directly influence the type, intensity, and sustainability of interventions.

This study presented some limitations, including the limited number of clinical investigations exploring the relationship between PA and improvements in executive and motor functions. However, the studies reviewed were published in high-impact journals indexed in the Web of Science (WoS), ensuring the quality and relevance of the analyzed evidence. Additionally, the therapeutic approaches involving PA and PE proved to be effective and safe options for individuals with ASD, supporting their potential as viable treatment modalities for this population.

### Clinical Implications

There remains a clear need to incorporate PA and/or PE as therapeutic approaches and to conduct additional RCTs involving these modalities. This review underscores their potential as evidence-based treatment options for individuals with ASD. Furthermore, the findings provide valuable insights for physical education professionals and physiotherapists seeking to promote better functional outcomes and to offer alternative interventions that support both individuals with ASD and their families.

## Conclusion

Protocols incorporating at least two sessions per week over a period of eight weeks appear to yield better prognoses for individuals diagnosed with ASD. Significant enhancements have been reported in motor skills, adaptive behavior, social skills, and cognitive functioning following the implementation of PA programs, particularly when adapted through game-based activities in daily life. PE programs also demonstrate relevance, especially regarding the frequency and duration of their implementation. Regarding imitation mirroring activities in individuals with ASD, although these do not directly increase empathy, they can enhance self-reported well-being, social competence, and body awareness.

Therefore, this study advocates for the development of structured protocols using mixed methods designs that integrate both qualitative and quantitative approaches. Such frameworks may enable a deeper understanding of the emotional experiences and cognitive processes of individuals with ASD prior to quantification, thereby informing the design of evidence-based interventions tailored to the complex and diverse needs within the autism spectrum.

## Conflict of Interest

The authors declare that they have no competing interests.

## Researchers' Contribution Statement

Conception of the study, drafting, and critical revision of the manuscript were contributed by all authors; all authors provided final approval of the manuscript.

## Authors' Contributions

Study design: CRB, JS, TCS; Data collection: CRB, JS, TCS, RF; Statistical analysis: CRB, JS, TCS, IBN; Data interpretation: CRB, JS, TCS, IBN; Literature search: CRB, JS, TCS; Manuscript writing: CRB, JS, TCS, RF; All authors read and approved the published version of the manuscript.

## REFERENCES

- Alabdulkareem, A., Alhakbani, N., & Al-Nafjan, A. (2022). A systematic review of research on robot-assisted therapy for children with autism. *Sensors*, 22(3), 944. [[CrossRef](#)] [[PubMed](#)]
- American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders, 5th edn Arlington, VA: American Psychiatric Publishing, 10. [[CrossRef](#)]
- Barrios-Fernández, S., Carlos-Vivas, J., Muñoz-Bermejo, L., Mendoza-Muñoz, M., Apolo-Arenas, M. D., García-Gómez, A., & Adsuar, J. C. (2022). Effects of square-stepping exercise on motor and cognitive skills in autism spectrum disorder children and adolescents: a study protocol. *Healthcare*, 10(3), 450. [[CrossRef](#)] [[PubMed](#)]
- Bitencourt, C. R., Fleig, R., & do Nascimento, I. B. (2023). Desempenho funcional no transtorno do espectro autista: interação social, sensorial e consciência corporal. *Revista Família, Ciclos de Vida e Saúde no Contexto Social*, 11(4), e6836-e6836. [[CrossRef](#)]
- Bremer, E., Crozier, M., & Lloyd, M. (2016). A systematic review of the behavioural outcomes following exercise interventions for children and youth with autism spectrum disorder. *Autism*, 20(8), 899-915. [[CrossRef](#)] [[PubMed](#)]
- Carneiro, T., Carvalho, A., Frota, S., & Filipe, M. G. (2024). Serious games for developing social skills in children and adolescents with autism spectrum disorder: A systematic review. *Healthcare*, 12(5), 508. [[CrossRef](#)] [[PubMed](#)]
- Dehghani, M., Jafarnejadgero, A. A., Darvishani, M. A., Aali, S., & Granacher, U. (2023). Effects of an 8-week multimodal exercise program on ground reaction forces and plantar pressure during walking in boys with autism spectrum disorder. *Trials*, 24(1), 170. [[CrossRef](#)] [[PubMed](#)]
- Deng, J., Lei, T., & Du, X. (2023). Effects of sensory integration training on balance function and executive function in children with autism spectrum disorder: evidence from Footscan and fNIRS. *Frontiers in Psychology*, 14, 1269462. [[CrossRef](#)] [[PubMed](#)]
- Elliott Jr, R. O., Dobbin, A. R., Rose, G. D., & Soper, H. V. (1994). Vigorous, aerobic exercise versus general motor training activities: Effects on maladaptive and stereotypic behaviors of adults with both autism and mental retardation. *Journal of Autism And Developmental Disorders*, 24(5), 565-576. [[CrossRef](#)] [[PubMed](#)]
- Fears, N. E., Sherrod, G. M., Blankenship, D., Patterson, R. M., Hynan, L. S., Wijayasinghe, I., & Miller, H. L. (2023). Motor differences in autism during a human-robot imitative gesturing task. *Clinical Biomechanics*, 106, 105987. [[CrossRef](#)] [[PubMed](#)]
- Figari, C. A., & Fernández Unsain, R. A. (2023). Social representations of disability: Between models and persons. Debates and perspectives on the dynamics of social interactions. *Spanish Journal of Disability Studies*, 11(2). [[CrossRef](#)]
- Freire, J. M. M., & Nogueira, G. S. (2023). Considerações sobre a prevalência do autismo no brasil: uma reflexão sobre inclusão e políticas públicas. *Revista foco*, 16(3), e1225-e1225. [[CrossRef](#)]
- Graham, T. N., King, N., Coe, H., Zabochnikova, P., Gurd, B. J., & Samdup, D. (2022). Design and evaluation of an exergaming system for children with autism spectrum disorder: The children's and families' perspective. *Frontiers in Virtual Reality*, 3, 817303. [[CrossRef](#)]

- Gringras, P., Nir, T., Breddy, J., Frydman-Marom, A., & Findling, R. L. (2017). Efficacy and safety of pediatric prolonged-release melatonin for insomnia in children with autism spectrum disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, 56(11), 948-957. [CrossRef] [PubMed]
- Hayes, C., Simmons, M., Simons, C., & Hopwood, M. (2018). Evaluating effectiveness in adolescent mental health inpatient units: A systematic review. *International Journal of Mental Health Nursing*, 27(2), 498-513. [CrossRef] [PubMed]
- Herrera, S. G. R., Leon-Rojas, J. E., & Herrera, S. G. R. (2024). The effect of aerobic exercise in neuroplasticity, learning, and cognition: a systematic review. *Cureus*, 16(2). [CrossRef] [PubMed]
- Herrero, R., Díaz, A., & Zueco, J. (2024). The burden and psychological distress of family caregivers of individuals with autism spectrum disorder: A gender approach. *Journal of Clinical Medicine*, 13(10), 2861. [CrossRef] [PubMed]
- Jpt, H. (2008). Cochrane handbook for systematic reviews of interventions. <http://www.cochrane-handbook.org>.
- Jia, M., Zhang, J., Pan, J., Hu, F., & Zhu, Z. (2024). Benefits of exercise for children and adolescents with autism spectrum disorder: a systematic review and meta-analysis. *Frontiers in Psychiatry*, 15, 1462601. [CrossRef] [PubMed]
- Johnson, R. W., Williams, S. A., Gucciardi, D. F., Bear, N., & Gibson, N. (2020). Can an online exercise prescription tool improve adherence to home exercise programmes in children with cerebral palsy and other neurodevelopmental disabilities? A randomised controlled trial. *BMJ Open*, 10(12), e040108. [CrossRef] [PubMed]
- Kou, R., Li, Z., Li, M., Zhou, R., Zhu, F., Ruan, W., & Zhang, J. (2024). Comparative effectiveness of physical exercise interventions on sociability and communication in children and adolescents with autism: a systematic review and network meta-analysis. *BMC psychology*, 12(1), 712. [CrossRef] [PubMed]
- Lang, R., Koegel, L. K., Ashbaugh, K., Regester, A., Ence, W., & Smith, W. (2010). Physical exercise and individuals with autism spectrum disorders: A systematic review. *Research in Autism Spectrum Disorders*, 4(4), 565-576. [CrossRef]
- Laguna, G. G. D. C., Gusmão, A. B. F., Marques, B. O., Bragas, N. B. D. S., Rodrigues, I. B., Melo, R. S., & Azevedo, K. R. M. D. (2025). Neuroplasticity in autism spectrum disorder: a systematic review. *Dementia & Neuropsychologia*, 19, e20240182. [CrossRef] [PubMed]
- Levinson, L. J., & Reid, G. (1993). The effects of exercise intensity on the stereotypic behaviors of individuals with autism. *Adapted Physical Activity Quarterly*, 10(3), 255-268. [CrossRef]
- Li, C., Belter, M., Liu, J., & Lukosch, H. (2023). Immersive virtual reality enabled interventions for autism spectrum disorder: A systematic review and meta-analysis. *Electronics*, 12(11), 2497. [CrossRef]
- Li, H., & Zhang, R. (2025). The effect of exercise intervention on balance and executive function in children with autism spectrum disorder: a meta-analysis. *BMC Sports Science, Medicine and Rehabilitation*, 17(1), 80. [CrossRef] [PubMed]
- Luelmo, P., Kasari, C., & Fiesta Educativa, Inc. (2021). Randomized pilot study of a special education advocacy program for Latinx/minority parents of children with autism spectrum disorder. *Autism*, 25(6), 1809-1815. [CrossRef] [PubMed]
- Mastrominico, A., Fuchs, T., Manders, E., Steffinger, L., Hirjak, D., Sieber, M., Thomas, E., Holzinger, A., Konrad, A., Bopp, N., & Koch, S. C. (2018). Effects of dance movement therapy in adults with autism spectrum disorder: A randomized controlled trial. *Behavioral Sciences*, 8(7), 61. [CrossRef] [PubMed]
- McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia Medica*, 22(3), 276-282. [PubMed]
- Moraes, Í. A. P., Monteiro, C. B. D. M., Silva, T. D. D., Massetti, T., Crocetta, T. B., de Menezes, L. D. C., & Magalhães, F. H. (2020). Motor learning and transfer between real and virtual environments in young people with autism spectrum disorder: A prospective randomized cross over controlled trial. *Autism Research*, 13(2), 307-319. [CrossRef] [PubMed]
- Murad, M. H., Asi, N., Alsawas, M., & Alahdab, F. (2016). New evidence pyramid. *BMJ Evidence-Based Medicine*, 21(4), 125-127. [CrossRef] [PubMed]
- Nascimento, I. B. D., Bitencourt, C. R., & Fleig, R. (2021). Estratégias para o transtorno do espectro autista: interação social e intervenções terapêuticas. *Jornal Brasileiro de Psiquiatria*, 70, 179-187. [CrossRef]
- National Institutes of Health. (2021). Study quality assessment tools.
- Nekar, D. M., Lee, D. Y., Hong, J. H., Kim, J. S., Kim, S. G., Seo, Y. G., & Yu, J. H. (2022). Effects of augmented reality game-based cognitive-motor training on restricted and repetitive behaviors and executive function in patients with autism spectrum disorder. *Healthcare*, 10(10), 1981. [CrossRef] [PubMed]
- Okkenhaug, I., Jensen, M. R., & Solhaug, S. (2024). Barriers and facilitators for physical activity among children and youth with autism: A scoping review. *Journal of Physical Activity and Health*, 21(10), 965-979. [CrossRef] [PubMed]
- Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan: A web and mobile application for systematic reviews. *Systematic Reviews*, 5, 210. [CrossRef] [PubMed]
- Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ*, 372, n160. [CrossRef] [PubMed]
- Pan, C. Y. (2010). Effects of water exercise swimming program on aquatic skills and social behaviors in children with autism spectrum disorders. *Autism*, 14(1), 9-28. [CrossRef] [PubMed]
- Pan, C. Y., Tsai, C. L., Chen, F. C., Chow, B. C., Chen, C. C., & Chu, C. H. (2021). Physical and sedentary activity patterns in youths with autism spectrum disorder. *International Journal of Environmental Research and Public Health*, 18(4), 1739. [CrossRef] [PubMed]

- Prieto, L. A., Meera, B., Barry, A., Swarup, G., Asmus, J., Ku, B., & Columna, L. (2023). A randomized parent-mediated physical activity intervention for autistic children. *Autism Research, 16*(7), 1450-1461. [CrossRef] [PubMed]
- PROSPERO. (2024). *International prospective register of systematic reviews*. University of York.
- Rafiei Milajerdi, H., Sheikh, M., Najafabadi, M. G., Saghaei, B., Naghdi, N., & Dewey, D. (2021). The effects of physical activity and exergaming on motor skills and executive functions in children with autism spectrum disorder. *Games for Health Journal, 10*(1), 33-42. [CrossRef] [PubMed]
- Rocha, L. C. S., Monteiro, S. R. A., Ribeiro, L. L., & Farias, R. R. S. (2024). O desafio da inclusão escolar de crianças com autismo: Uma perspectiva dos professores. *Revista Contemporânea, 4*(9), 1–25. [CrossRef]
- Rosenthal-Malek, A., & Mitchell, S. (1997). Brief report: the effects of exercise on the self-stimulatory behaviors and positive responding of adolescents with autism. *Journal of Autism & Developmental Disorders, 27*(2). [CrossRef] [PubMed]
- Santa Catarina, Secretaria de Estado da Educação. (2018). Política de educação especial do estado de Santa Catarina (PEE-SC).
- Sánchez Amate, J. J., & Luque de la Rosa, A. (2024). The effect of autism spectrum disorder on family mental health: Challenges, emotional impact, and coping strategies. *Brain Sciences, 14*(11), 1116. [CrossRef] [PubMed]
- Santos, C. M. D. C., Pimenta, C. A. D. M., & Nobre, M. R. C. (2007). The PICO strategy for the research question construction and evidence search. *Revista Latino-Americana de Enfermagem, 15*(3), 508-511. [CrossRef] [PubMed]
- Sarkies, M. N., Bowles, K. A., Skinner, E. H., Haas, R., Lane, H., & Haines, T. P. (2017). The effectiveness of research implementation strategies for promoting evidence-informed policy and management decisions in healthcare: a systematic review. *Implementation Science, 12*(1), 132. [CrossRef] [PubMed]
- Schildt, H. A. (2002). Sitkis: software for bibliometric data management and analysis. *Helsinki: Institute of Strategy and International Business, 6*(1).
- Schmidt, C., Mainardes, J., & Vieira, A. M. D. P. (2024). Editoração de periódicos científicos em educação: tópicos contemporâneos. *Revista Diálogo Educacional, 24*(82), 859-865. [CrossRef]
- Singh, B., Bennett, H., Miatke, A., Dumuid, D., Curtis, R. G., Ferguson, T., et al. (2025). Effectiveness of exercise for improving cognition, memory and executive function: a systematic umbrella review and meta-meta-analysis. *British Journal of Sports Medicine, 59*(12), 866-876. [CrossRef] [PubMed]
- Sorensen, C., & Zarrett, N. (2014). Benefits of physical activity for adolescents with autism spectrum disorders: A comprehensive review. *Review Journal of Autism and Developmental Disorders, 1*(4), 344-353. [CrossRef]
- Sowa, M., & Meulenbroek, R. (2012). Effects of physical exercise on autism spectrum disorders: A meta-analysis. *Research in Autism Spectrum Disorders, 6*(1), 46-57. [CrossRef]
- Suarez-Manzano, S., Ruiz-Ariza, A., de Loureiro, N. E. M., & Martinez-Lopez, E. J. (2024). Effects of physical activity on cognition, behavior, and motor skills in youth with autism spectrum disorder: A systematic review of intervention studies. *Behavioral Sciences, 14*(4), 330. [CrossRef] [PubMed]
- Todd, T., & Reid, G. (2006). Increasing physical activity in individuals with autism. *Focus On Autism and Other Developmental Disabilities, 21*(3), 167-176. [CrossRef]
- Toscano, C. V., Carvalho, H. M., & Ferreira, J. P. (2018). Exercise effects for children with autism spectrum disorder: metabolic health, autistic traits, and quality of life. *Perceptual and Motor Skills, 125*(1), 126-146. [CrossRef] [PubMed]
- Van Niekerk, K., Stancheva, V., & Smith, C. (2023). Caregiver burden among caregivers of children with autism spectrum disorder. *South African Journal of Psychiatry, 29*, 2079. [CrossRef] [PubMed]
- Wang, S., Chen, D., Yang, Y., Zhu, L., Xiong, X., & Chen, A. (2023). Effectiveness of physical activity interventions for core symptoms of autism spectrum disorder: a systematic review and meta-analysis. *Autism Research, 16*(9), 1811-1824. [CrossRef] [PubMed]
- Watters, R. G., & Watters, W. E. (1980). Decreasing self-stimulatory behavior with physical exercise in a group of autistic boys. *Journal of Autism and Developmental Disorders, 10*(4), 379-387. [CrossRef] [PubMed]
- Yang, J., & Li, R. (2025). Systematic review and randomized controlled trial meta-analysis of the effects of physical activity interventions and their components on repetitive stereotyped behaviors in patients with autism spectrum disorder. *Frontiers in Psychology, 16*, 1579345. [CrossRef] [PubMed]
- Zadok, E., Gordon, I., Navon, R., Rabin, S. J., & Golan, O. (2022). Shifts in behavioral synchrony in response to an interaction partner's distress in adolescents with and without ASD. *Journal of Autism and Developmental Disorders, 52*(10), 4261-4273. [CrossRef] [PubMed]
- Zhao, M., Chen, S., You, Y., Wang, Y., & Zhang, Y. (2021). Effects of therapeutic horseback riding on social interaction and communication in children with autism. *International Journal of Environmental Research and Public Health, 18*, 2656. [CrossRef] [PubMed]



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