Title: The Impact of Exercise Interventions on Emotional Regulation, Anxiety, and Social Skills in Children with Autism Spectrum Disorder: A Systematic Review and Meta-Analysis

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To appear in: ***Physical Treatments***

Received date: 2025/10/25

Revised date: 2026/02/10

Accepted date: 2026/04/09

First Online Published: 2026/06/23

Please cite this article as:

Dehghani M, Rezazadeh F, Qasemi M, Safajou H, Piri E. The Impact of Exercise Interventions on Emotional Regulation, Anxiety, and Social Skills in Children with Autism Spectrum Disorder: A Systematic Review and Meta-Analysis. ***Physical Treatments.*** Forthcoming 2026. DOI: http://dx.doi.org/10.32598/ptj.2026.776.1

DOI: http://dx.doi.org/10.32598/ptj.2026.776.1

Abstract

Background: Children with autism spectrum disorder often exhibit difficulties in emotion regulation, elevated anxiety levels, and deficits in social functioning. This systematic review and meta-analysis aimed to critically evaluate the evidence on the effectiveness of exercise interventions in improving emotion regulation, reducing anxiety, and enhancing social skills among children with autism spectrum disorder.

Methods: This review followed the PRISMA 2020 guidelines. Four databases PubMed, Scopus, Web of Science, and Google Scholar were systematically searched for randomized controlled, quasi-experimental, and non-randomized studies published from January 2015 to February 2026. Eligible studies included children with a formal autism spectrum disorder diagnosis who participated in structured exercise programs targeting at least one of the three outcomes. Methodological quality was assessed using the McMaster and PEDro scales.

Findings: A total of 16 studies involving 569 children with ASD (mean age 8.05 years; 81% boys) were included. For social skills, meta-analysis of 13 studies showed a small, non-significant overall effect (SMD = 0.16, p = 0.62), with considerable heterogeneity (I^2 = 87%). Most individual studies (14 of 16) reported positive improvements in this domain. Regarding emotional regulation, a significant baseline deficit was identified in children with ASD compared to TD peers (pooled SMD = −0.64, p = 0.008). Following exercise interventions, enhancements in emotion regulation were reported in four studies. Only one study measured anxiety outcomes, precluding a pooled analysis; however, it found a reduction in anxiety symptoms post-intervention.

Conclusion: Collectively, the evidence indicates that structured exercise interventions may benefit children with ASD, though the strength and consistency of effects vary across outcomes. Meta-analysis showed a small, non-significant pooled effect on social skills, with high heterogeneity suggesting that intervention success may depend on program characteristics and measurement approaches.

Keywords: Autism, Physical Activity, Emotion Regulation, Anxiety, Social Skills.

Highlights

- Structured exercise interventions significantly improve social skills in children with autism spectrum disorder.
- Physical activity shows potential benefits for emotion regulation and anxiety reduction.
- Martial arts, dance, and mini-basketball yield the strongest psychosocial improvements.

Plain Language Summary

Children with autism spectrum disorder frequently experience challenges with emotion regulation, anxiety, and social interaction. This review examined whether structured exercise can serve as an accessible and beneficial intervention.

An analysis of recent research involving activities like martial arts, dance, and team sports demonstrated that regular physical activity can be an effective therapeutic tool. Findings indicate that exercise programs can significantly enhance social skills, such as communication and cooperation. Additionally, benefits were observed in improved emotional control and reduced anxiety for some children.

The evidence suggests that integrating tailored exercise into daily routines offers a practical and low-cost strategy to support the emotional and social development of children with autism, complementing existing therapies.

1. Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition that typically emerges in early childhood and is characterized by persistent difficulties in social communication and interaction, along with restricted and repetitive behaviors, interests, or activities (1). The presentation and severity of ASD symptoms vary widely, ranging from mild functional challenges to severe impairments that significantly affect daily life. Over the past two decades, increased awareness and changes in diagnostic practices have contributed to a marked rise in ASD prevalence worldwide. According to data from the Autism and Developmental Disabilities Monitoring (ADDM) Network of the Centers for Disease Control and Prevention (CDC), ASD prevalence increased from approximately 1 in 150 children in 2000 to 1 in 36 children in 2020 (2). ASD is also reported to be more prevalent in boys than girls, although emerging evidence suggests that females may be underdiagnosed due to sex-related differences in symptom presentation (2).

Beyond the core features related to communication and social interaction outlined in the DSM-5 diagnostic criteria (1), research since the 1990s has also highlighted significant delays in motor development among children with autism (3-4). Various studies have found that these children tend to have weaker fine and gross motor skills compared to their peers, and these motor difficulties can also impact their social interactions and participation in group activities (5-7). This underscores the importance of developing strategies to improve both social and motor skills in this population.

Because motor skills are closely linked to opportunities for group play, social interaction, and building self-confidence, improving these skills can indirectly strengthen social functioning (8). Some studies have also pointed to a strong connection between motor disorders and poor social communication in children with autism (9-10). These findings suggest that physical activity-based interventions can play an important role in enhancing social interactions for these children (11).For example, a study by Tse and colleagues demonstrated that a 12-week basketball program improved executive functions, including working memory and inhibitory control, with significant gains in inhibitory control among children with ASD (12). Similarly, Diamond and Ling have suggested that physical activities involving high cognitive and social engagement, such as martial arts or dance, have an even greater positive impact on executive functions (13).

Despite the growing body of research on motor and social functioning in children with autism, less attention has been given to how exercise interventions affect emotion regulation and anxiety in

this group. Various theories have explored why anxiety levels tend to be higher in individuals with autism. Some suggest anxiety arises from a fear of environmental changes and unfamiliar situations (14), while others propose it stems from an awareness of personal limitations or difficulties with empathy (15-16). These factors can lead to increased social isolation, inappropriate interactions, and avoidance of social situations, creating a negative cycle that affects the child's psychosocial well-being.

There is evidence that physical activity can effectively reduce anxiety in the general population. This benefit is thought to come from mechanisms such as increased self-efficacy, better quality of life, reduced sensitivity to anxiety, and regulation of the hypothalamic-pituitary-adrenal (HPA) axis (17). Physical activity may also improve emotion regulation by stimulating brain pathways involved in stress control. For instance, a study by Broman et al. found that even low-intensity physical activity can lower anxiety sensitivity (18).

Given the high costs and specialized expertise required for conventional treatments like pharmacotherapy, cognitive behavioral therapy, and relaxation techniques (19-20), physical activity has gained recognition as a complementary and accessible approach in comprehensive intervention programs. Since childhood is a critical period for psychosocial development, it is important to examine how exercise activities can improve key areas such as emotion regulation, anxiety, and social skills. Although research in this area has expanded, to date, no systematic and comprehensive review has simultaneously examined the effects of exercise interventions on these three important variables in children with autism. Therefore, this study aims to fill that gap by systematically reviewing the existing evidence on how physical activity influences emotion regulation, anxiety, and social skills in children with ASD.

2.Methods

2.1. Protocol and Registration

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. No prior registration was completed in PROSPERO or other registries; however, the review protocol was predefined in terms of scope, eligibility criteria, and analytical procedures to ensure transparency and reproducibility (21). At the outset, the PICO framework (Population, Intervention, Comparison, Outcome) was used to formulate the research question (22).

2.2. Search strategy

To identify eligible studies, a comprehensive and systematic search was performed in PubMed, Scopus, Web of Science, and Google Scholar for articles published between January 1, 2015, and May 1, 2025. The search strategy was designed based on the PICO framework and included three main domains: 1- terms related to the target population, such as Autism Spectrum Disorder, Autism, Autistic Disorder, and *ASD*; 2- keywords related to exercise and physical activity interventions, including Exercise, Physical Activity, Sports, Exercise Therapy, Aerobic Exercise, Resistance Training, Martial Arts, Football, Basketball, Soccer, Running, Swimming, Dance, Yoga, Core Stability, and Neuromuscular Training; and 3- terms related to age groups and outcomes, such as Child, Adolescent, Preschool, Youth, and Student, along with concepts including Emotion Regulation, Anxiety, Social Skills, Social Interaction, and Communication. These keywords were combined using Boolean operators (AND, OR) to maximize both coverage and precision in identifying relevant studies.

2.3. Inclusion and Exclusion Criteria

The inclusion criteria were as follows: publication date between January 1, 2015, and February 1, 2026; study design limited to randomized controlled trials, quasi-randomized controlled trials, or quasi-experimental studies; participants formally diagnosed with autism by recognized institutions; and interventions consisting of various forms of physical activity, either group-based or individual, including but not limited to aerobic, resistance, and flexibility exercises. Participants were required to engage in the interventions regularly to ensure continuity and potential long-term effects, with a minimum duration of two weeks. Control groups were defined as receiving no exercise interventions, providing a baseline against which the effectiveness of physical activity programs could be evaluated.

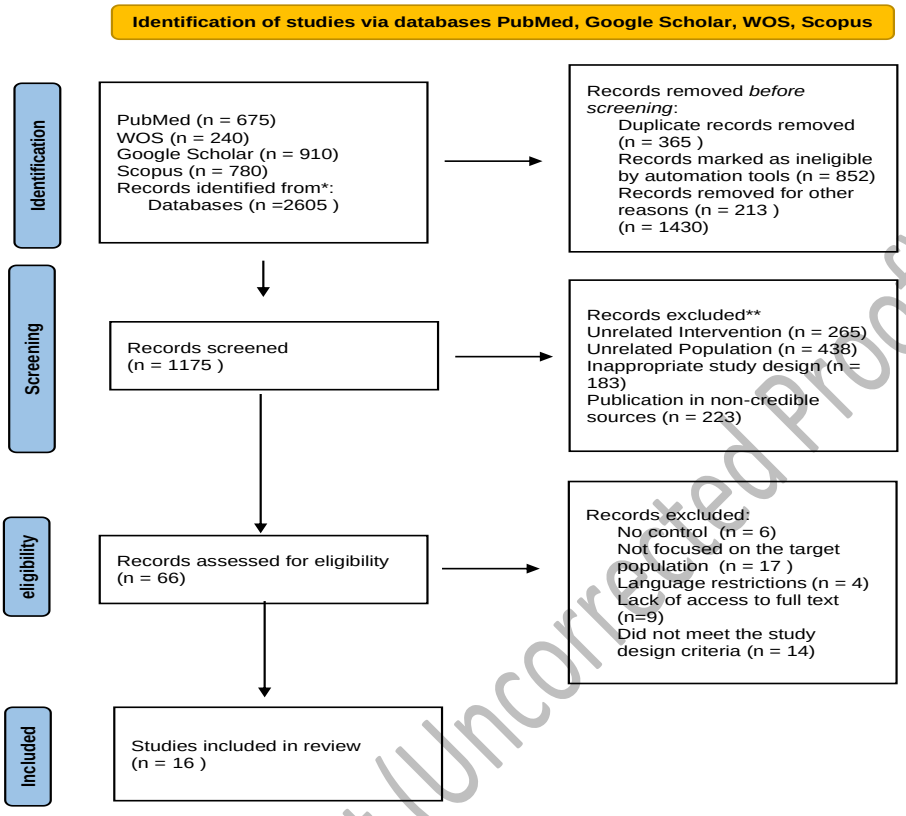

Fig1. PRISMA flow diagram**.**

2.4. Study Selection and Data Extraction

Two reviewers independently screened the titles and abstracts of identified articles based on predefined inclusion and exclusion criteria. Their results were then compared, and lists were merged to identify discrepancies. Any disagreements were resolved through discussion, and if consensus was not achieved, a third reviewer assessed the disputed studies and made the final decision. Studies with insufficient descriptions of the intervention or missing mean values were also reviewed by the third investigator. After screening, relevant information from the included studies was extracted and compiled. Extracted data covered basic study characteristics (author, country, year of publication), trial design details (ASD diagnostic criteria, age range, mean age, sample size of intervention and control groups, gender ratio), exercise intervention characteristics (type of activity, duration, frequency, control measures), and outcome measures for anxiety,

emotion regulation, and social skills (including pre- and post-intervention means and standard deviations).

2.5. Quality Assessment

The methodological quality of the included studies was assessed using the McMaster Critical Review Form for Quantitative Studies (23). This tool consists of 16 items covering essential elements such as study purpose, research design, sampling, outcome measurement, intervention, results, and conclusions. Each item was scored as 1 if the criterion was met and 0 if not, with total scores categorizing studies as weak (0–8), moderate (9–10), good (11–12), very good (13–14), or excellent (15–16). In addition, randomized controlled trials (RCTs) were further assessed using the PEDro scale to evaluate risk of bias (24). This 11-item scale assigns scores of 0 or 1 for each item, with studies categorized as poor (<3), fair (4–5), good (6–7), or excellent (8–11) (24).

2.6. Data Synthesis and Analysis

After final study selection, two reviewers independently extracted key data using a standardized form. This included study characteristics (author and year), research design, participant details (sample size, age, sex), intervention specifics (type, duration, frequency), control group characteristics, and measurement tools along with outcome data (means and standard deviations). Methodological quality and risk of bias were assessed using the McMaster tool and PEDro scale. Due to substantial heterogeneity among studies in terms of exercise type and duration, outcome measures, and participant characteristics, a quantitative meta-analysis was not feasible. Instead, findings were synthesized narratively. Results were organized and interpreted across the three main outcome domains social skills, anxiety, and emotion regulation with particular emphasis on studies of higher methodological quality.

2.7. Data Synthesis and Rationale for Narrative Synthesis

Due to substantial heterogeneity across the included studies, a quantitative meta-analysis was not feasible. The sources of heterogeneity included marked variations in study design (randomized, quasi-experimental, and non-randomized trials), participant characteristics (age range, sex distribution, ASD severity), intervention protocols (type of exercise, intensity, frequency, duration, and delivery setting), and outcome assessment tools used to measure social skills, anxiety, and emotion regulation. These methodological and clinical differences limited the comparability of effect sizes and prevented meaningful statistical pooling of data.

Therefore, a narrative synthesis approach was adopted as the most appropriate method to compare, interpret, and integrate the findings across studies. Extracted data were systematically organized according to intervention type (e.g., martial arts, aerobic training, dance therapy, sensorimotor and neuromuscular exercises) and outcome domain (social skills, anxiety, and emotion regulation). Greater interpretive weight was given to studies with higher methodological quality based on McMaster and PEDro scores. This comparative narrative approach enabled the identification of consistent patterns, similarities, and divergences in intervention effects, while accounting for heterogeneity and risk of bias, and provided a structured framework for drawing cautious and evidence-informed conclusions

3. Results

3.1. Study selection

The study selection process followed the PRISMA guidelines. Initially, 2,605 records were identified through searches in PubMed, Web of Science, Google Scholar, and Scopus. After removing duplicates, 1,175 studies remained for screening based on titles and abstracts. Of these, 1,111 were excluded because they involved irrelevant populations or interventions, had inappropriate study designs, or were published in non-academic sources. This left 66 full-text articles to be assessed for eligibility. Further exclusions were made due to reasons such as lack of control groups, focus outside the target population, short intervention durations, inaccessible full texts, or failure to meet design criteria. Ultimately, 16 studies were included in the systematic review.

3.2. Quality Assessment

Quality assessment using the McMaster and PEDro scales showed that the methodological quality of the included studies ranged from good to excellent. On the McMaster scale, scores varied between 10 and 16, with the highest score of 16 out of 16 awarded to the study by Dhingra et al. (2025) (Table 1 Similarly, on the PEDro scale, scores ranged from 7 to 10, with the same study receiving a perfect score of 10 out of 10 (Table 2). These results reflect transparent reporting and effective control of bias in most of the included studies. Participants in the reviewed studies ranged in age from 3 to 13 years, with an average age of about 8.05 years. Among the 569 children involved, approximately 81% were boys, which aligns with the known higher prevalence of ASD in males. The interventions covered a broad range of activities, including sensorimotor play, martial arts such as judo and karate, aerobic training, combined football and basketball programs,

dance therapy, structured group activities, and cycling exercises. The duration of these interventions varied from 2 to 24 weeks, with sessions held 2 to 5 times per week.

When looking at outcomes, social skills were the most commonly reported area of improvement, with 14 studies (87.5%) documenting significant gains. Anxiety was assessed in 3 studies (18.75%), all of which found reductions in anxiety levels and improvements in psychological calmness. Emotion regulation and self-regulation were evaluated in 4 studies (25%), showing enhancements in emotional control, behavioral inhibition, and emotional self-efficacy. Additionally, motor performance was examined as a secondary outcome in 6 studies (37.5%), with improvements noted in coordination, balance, locomotor skills, and object control. A summary of these findings is provided in Table 3.

Some studies also reported positive effects of the interventions on neurobiological markers, such as regional homogeneity and white matter integrity (WMI), which were linked to better social and cognitive functioning. Interventions that involved interactions with typically developing peers not only boosted social skills in children with ASD but also fostered more positive attitudes toward them among their peers. Overall, the findings suggest that structured exercise programs tailored to the unique needs of children with ASD, and delivered with the guidance of trained coaches and specialists, can be effective, cost-efficient, and practical approaches in both educational and rehabilitative settings. These programs contribute to improved social skills, reduced anxiety, and better self-regulation in children with ASD.

Table 1. Quality Assessment of Included Studies Using the McMaster Critical Review Form

Author (Year)	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Item 13	Item 14	Item 15	Item 16	Total Score	Rating
Lingtao Wen (2025)	1	1	1	0	1	0	1	1	1	0	1	1	1	1	1	0	12	Good
Phoebe O. Morris (2025)	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0	0	11	Good
Nicole Maussier (2025)	1	1	0	0	1	0	1	1	1	1	1	1	1	1	0	0	11	Good
Anju Dhingra (2025)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16	Excellent
Yu Xing (2025)	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	14	Very Good
Yang Yang (2024)	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	13	Very Good
Morteza Homayounnia Firouzjah (2024)	1	1	1	0	1	0	1	1	1	1	1	1	1	1	0	1	13	Very Good
Andy CY Tse (2024)	1	1	1	0	1	1	1	0	1	0	1	1	0	1	0	0	10	Good
Kai Qi (2024)	1	1	0	1	1	1	1	1	1	0	1	1	1	1	0	1	13	Very Good
Xiaorui Cui (2024)	1	1	0	0	1	0	1	1	1	0	1	1	1	1	0	0	10	Good
Amir Hossein Haghighi (2023)	1	1	1	0	1	1	1	1	1	0	1	1	1	1	0	1	13	Very Good
Jean-G. Gehricke (2022)	1	1	0	0	1	0	1	1	0	1	1	1	1	1	1	1	12	Good
Jose Maria Lopez-Diaz (2021)	1	1	0	0	1	0	1	1	1	1	1	0	1	1	0	0	10	Good
Ahmet Sansi (2021)	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	14	Very Good
Gianpieri Greco (2020)	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	13	Very Good
Kelong Cai (2020)	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	13	Very Good

Table 2. Quality Assessment of Randomized Clinical Trials Using the PEDro Scale

Author (Year)	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total Score	Rating
Anju Dhingra (2025)	1	1	1	1	1	0	1	1	1	1	1	10	Excellent
Andy CY Tse (2024)	1	1	1	1	1	0	0	0	1	1	1	8	Excellent
Xiaorui Cui (2024)	1	1	1	0	0	0	0	1	1	1	1	7	Good
Amir Hossein Haghighi (2023)	1	1	1	1	0	0	0	1	1	1	0	7	Good
Jean-G. Gehricke (2022)	1	1	1	1	1	0	0	0	0	1	1	7	Good
Gianpieri Greco (2020)	1	1	1	1	0	0	0	1	1	1	1	8	Excellent

Table 3. Summary of Included Studies Examining the Effects of Exercise Interventions on Emotion Regulation, Anxiety, and Social Skills in Children with Autism Spectrum Disorder.

Author(s)/ Journal/ Publication Year	Participants (Age, Sex/Gender)	Study Design	Study Aim/Purpose	Variables Assessed/Examined	Control Group	Duration	Exposure	Outcome Measures	Key Findings
Lingtao Wen/ journal of scientific Reports/ 2025	40 children with autism/ aged between 6 and 12 years/ 30 boys and 10 girls	Quasi-experimental study	To investigate the effectiveness of sensory integration-based sports training in enhancing motor skills and social interaction among children with autism spectrum disorder (ASD)	Motor coordination, social responsiveness, and physical activity participation	Participated in standardized physical education-style activities, including aerobic games, ball handling, and calisthenics, without any sensory integration components	12-week intervention, 3×/week, 60 min/session	Sensory integration-based structured sports training	Bruininks-Oseretsky Test of Motor Proficiency (BOT-2), Social Responsiveness Scale (SRS-2), therapist observations, and attendance records	The intervention improved children's social participation, peer interaction, and motor coordination through structured sensory-based sports activities

Phoebe O. Morris et al. / International Journal of Developmental Disabilities / 2025	35 children with ASD; aged 8–12 years; 26 boys and 9 girls	Feasibility study (within-subject, pre-test/post-test design)	To assess the feasibility and potential efficacy of a dance-based exergame (Just Dance) for improving social communication skills in children with ASD within home and school settings.	Social communication skills, emotional regulation, adherence, and enjoyment	No active control group; within-subject comparison (pre-post)	6 weeks Frequency: 2 sessions/week at home (~25 minutes/session) Frequency: 5 sessions/week at school (~10 minutes/session, 2 songs/day)	Dance-based exergame (Just Dance) focused on mirroring, rhythm and interpersonal synchrony	ERSSQ-P (parents) and ERSSQ-T (teachers); enjoyability and adherence logs; home-based behavioural video observations coded via BORIS; semi-structured interviews with parents and staff.	The dance-based exergame was feasible and enjoyable, enhancing social communication and emotional engagement, particularly in schools, and showing potential as an accessible, low-cost support for children with ASD
Nicole Maussier et al. / Sport Sciences for Health / 2025	31 children with ASD (ASD); aged 6–10 years; 26 boys and 5 girls	Quasi-experimental study pre-test-post design without control group	To evaluate the effectiveness of school-based judo and karate programs in fostering social inclusion, enhancing gross motor skills, and reducing autism severity in children with ASD during curricular hours.	Autism severity, social impairment, and gross motor development	No control group; comparison made between judo and karate participant subgroups	24 weeks – Frequency: 2 sessions per week – Duration: 1 hour per session	Inclusive judo or karate adapted for ASD needs, using visual schedules, augmentative communication tools, and support from trained coaches and psychologists.	Gilliam Autism Rating Scale (GARS) – Social Responsiveness Scale (SRS) – Test of Gross Motor Development – 3rd edition (TGMD-3)	The intervention improved social inclusion, emotional regulation, and motor skills in children with ASD, with both judo and karate proving effective and well tolerated in inclusive schools.
Morteza Homayounnia Firouzjah et al. / Journal of Autism and Developmental Disorders / 2025	30 boys with ASD; aged 9–11 years;	Quasi-experimental study (QES) with control group; pre-test/post-test design	To investigate the effectiveness of sensory-motor integration exercises on social skills and motor performance in children with ASD	Social skills (including cooperation, self-control, and assertiveness) and motor performance (locomotor and object control skills)	Yes; received no intervention	4 Weeks – Frequency: 3 sessions per week – Duration: 45 minutes per session (12 sessions total)	Ayres-based sensory-motor exercises involving tactile, proprioceptive, and balance activities (e.g., crawling, rolling, pushing objects, balance board games).	– Gresham & Elliott's Social Skills Rating Scale (Teacher Version) – Ulrich's Motor Performance Test	The intervention enhanced social skills and motor performance in children with ASD, with experimental group gains in emotional control, peer interaction, and movement skills. .

Anju Dhingra et al. / Journal of Clinical and Diagnostic Research / 2025	38 children with mild to moderate ASD; aged 7–13 years; 36 boys and 2 girls;	Randomised Controlled Trial (RCT); single-blind, pre-test/post-test design	To study the effect of aerobic training on anxiety, activities of daily living (ADLs), and visual motor skills performance in children with ASD	Anxiety levels, functional independence in ADLs, and visual motor skills	Yes; received ASD awareness lectures only	8 weeks – Frequency: 3 sessions/week – Duration: 30 minutes/session	Aerobic program with walking, cycling, trampoline jumping, side shuffles, and aerobic games, delivered in two 4-week progressive phases under professional supervision.	– Screen for Child Anxiety Related Disorders (SCARED) – Functional Independence Measure (FIM) – Mirror Drawing Apparatus (electronic version	The aerobic training led to reduced anxiety, enhanced ability to perform daily living tasks, and improved visual motor coordination. The program was effective and well-received by children with ASD.
Yang Yang et al. / BMC Sports Science, Medicine and Rehabilitation / 2024	30 preschool children with ASD; aged 3–6 years; 26 boys and 4 girls	Quasi-experimental (2×2 mixed design); pre-test/post-test with control group	To examine the effects of a 12-week mini-basketball training program on social communication impairments and brain regional homogeneity (ReHo) in preschool children with ASD.	Social communication impairments (SCI), ReHo (resting-state brain activity)	Yes; received routine behavioral rehabilitation only	12 weeks – Frequency: 5 sessions/week – Duration: ~40 minutes/session	Mini-basketball training program (MBTP) involving basic ball-handling, passing, dribbling, and social interaction activities; implemented alongside regular rehabilitation	– Social Responsiveness Scale-2 (SRS-2) – Resting-state fMRI for ReHo analysis	The mini-basketball program enhanced social communication and promoted positive brain function changes, with intervention children showing improved social cognition, communication, and behavioral adaptation.
Yu Xing et al. / Frontiers in Psychology / 2025	21 children with ASD (ASD); aged 7–10 years; 16 boys and 5 girls	Quasi-experimental study; pre-test/post-test design with two control groups	To examine the effects of a 12-week group sports program on physical activity levels and social interaction abilities of children with ASD	Physical activity (sedentary, moderate-to-vigorous activity), social interaction states (e.g., joint participation, rule-based play)	Yes; one ASD control group (traditional school PE) and one group of typically developing children	12 Weeks – Frequency: 4 sessions/week – Duration: 60 minutes/session	Group sports activities including motor skill games, yoga, social stories, and structured interaction using evidence-based teaching strategies like CPRT	Physical activity: ActiGraph GT3X+ accelerometer – Social interaction: Playground Observation of Peer Engagement (POPE) – Autism symptoms: Childhood Autism Rating Scale (CARS)	The program reduced sedentary behavior and improved physical activity levels and social interaction skills. Children showed more joint participation and engagement in rule-based play.

Andy C.Y. Tse et al. / Autism / 2024	64 children with mild to moderate ASD (ASD); aged 8–12 years	Randomized Controlled Trial (RCT), three-arm parallel design	To compare cognitively engaging and non-cognitively engaging physical exercise on executive functions and self-regulation in children with ASD, and examine social, emotional, and physical factors as mediators.	Executive functions (cognitive flexibility, inhibition), self-regulation	Yes; active control group participated in daily walking	2 weeks – Frequency: 5 sessions/week – Duration: 60 minutes/session (10 sessions total)	Experimental: (1) Bicycle riding with progressive obstacles, (2) Stationary cycling; Active control: 20-min daily walks. All with structured instruction and 1:1 support.	Stroop Color and Word Test (SCWT) – Go/No-Go task – Response to Challenge Scale (RCS) – Self-report and observer-rated scales for mediators (e.g., perceived social support, enjoyment, stress, physical self-efficacy, perceived fitness)	Both cycling interventions improved executive functions and self-regulation, with greater gains in the bicycle riding group. Enhancements were partly mediated by increased self-efficacy and perceived social support.
Kai Qi et al. / BMC Sports Science, Medicine and Rehabilitation / 2024	41 preschool children with ASD (ASD); mean age ≈ 5 years	Multi-arm-controlled trial (3×2 mixed design); pre-test/post-test design	To compare the effects of a Ball Combination Training Program (BCTP) and Mini-Basketball Training Program (MBTP) versus standard behavioral rehabilitation on social communication impairments in preschool children with ASD	Social communication impairments (SCI) and its subdomains: social awareness, cognition, communication, motivation, and behavior pattern	Yes; received standard behavioral rehabilitation only	12 weeks – Frequency: 5 sessions/week – Duration: 40–45 minutes/session	BCTP: soccer + basketball with structured games; MBTP: basketball with motor tasks, imitation games, cooperative play. Both received standard behavioral rehabilitation.	Social Responsiveness Scale, 2nd edition (SRS-2), filled by parents – Subscales: Social Awareness, Cognition, Communication, Motivation, Behavior Pattern	Both programs improved social communication in children with ASD; BCTP mainly enhanced social awareness and behavior patterns, while MBTP improved social cognition and communication. Controls showed SCI decline.
Xiaorui Cui & Shan Wang / International Journal of Mental Health Promotion / 2024	24 boys with mild to moderate ASD (ASD); aged 6–12 years;	Randomized Controlled Trial (RCT); pre-test/post-test design	To explore the impact of a 12-week dance therapy intervention on motor, social, and communication skills in children with ASD	Gross motor skills (displacement, object control, balance, coordination), social responsiveness, communication behaviors	Yes; received no dance intervention	12 weeks – Frequency: 3 sessions/week – Duration: 80 minutes/session	Dance therapy including rhythmic and imitation-based movement activities tailored to autistic children, with group	– Childhood Autism Rating Scale (CARS) – Gross Motor Development Test (TGMD-3) – Social Responsiveness Scale (SRS)	Dance therapy improved motor coordination, balance, and social responsiveness. Children also showed increased eye contact and active communication during sessions.

							sessions and video-monitored observations	– Structured observation of eye contact, body movements, and verbal interactions	
Amir Hossein Haghighi et al. / Journal of Autism and Developmental Disorders / 2023	16 children with ASD (ASD); aged 6–10 years; 13 boys, 3 girls	Randomized Controlled Trial (RCT); pre-test/post-test design	To examine the effects of a combined physical training (CPT) program on social skills, stereotypic behaviors, and physical fitness in children with ASD	Stereotypic behavior, communication, social interaction, physical fitness (strength, power, flexibility, balance, agility, cardiorespiratory capacity)	Yes; received no physical training intervention	8 weeks – Frequency: 3 sessions/week – Duration: 60–80 minutes/session	Combined physical training program including ball games, rhythmic movements (dance), and resistance training using elastic bands	– Gilliam Autism Rating Scale – 2nd Edition (GARS-2) – Physical fitness tests (e.g., handgrip, sit-and-reach, agility T-test, Sargent jump)	The CPT intervention reduced stereotypic behaviors, improved communication skills, and enhanced several aspects of physical fitness including strength, flexibility, balance, and agility.
Jean-G. Gehricke et al. / Research in Autism Spectrum Disorders / 2022	148 underserved ASD / aged 6–12 years / 124 boys, 24 girls	Randomized Controlled Trial (RCT)	To examine the efficacy of an 8-week physical exercise intervention on anxiety in underserved children with ASD, compared to a sedentary LEGO/Minecraft activity	Anxiety, self-perceived anxiety, sleep disturbances, physical activity participation, physiological stress (cortisol)	Yes – the control group engaged in sedentary activities (LEGO/Minecraft) matched in duration and frequency	8 weeks – Frequency: 1–3 sessions/week – Duration: 40–50 minutes/session	Structured physical exercise program including aerobic, strength, agility, and obstacle-based activities led by trained instructors	CBCL DSM-5 anxiety subscale, SCARED questionnaire, CSHQ-ATN, PAQ-C, salivary cortisol levels	Anxiety levels significantly decreased in both groups; however, only the exercise group showed extended benefits at weeks 12 and 16. Physical activity increased and sleep improved in the exercise group; no significant cortisol changes observed
Jose Maria Lopez-Diaz et al. / Behavioral Sciences / 2021	13 boys with ASD (Level 1); aged 6–10 years	Pre-experimental study; pre-test/post-test without control group	To analyze the impact of a football training program on the development of social skills in children with ASD	Social skills (basic interaction, conversation, emotion-related skills, peer/adult relationships, cooperation, responsibility)	No control group; single-group repeated measures design	17 weeks – Frequency: 2 sessions/week – Duration: 60 minutes/session (34 sessions total)	Structured football training program including social games, technical drills, and small-sided matches adapted to individual needs	– Social Interaction Skills Questionnaire (CHIS; 6 dimensions) – Teacher Observation Scale (TOS; 6 dimensions)	Football training enhanced social skills especially politeness, emotion expression, and cooperation boosting peer interaction and positive behavior, with individual and skill-type variations.

Ahmet Sansi et al. / Journal of Autism and Developmental Disorders / 2021	45 students (22 with ASD, 23 typically developing); aged 6–11 years	Mixed-method (quantitative + qualitative); pre-test/post-test with control group	To examine the effects of an inclusive physical activity (IPA) program on the motor skills, social skills, and peer attitudes of children with and without ASD	Fundamental motor skills, social skills, peer attitudes	Yes; continued routine education without IPA program	12 weeks – Frequency: 2 sessions/week – Duration: 1 hour/session	Inclusive physical activity program including warm-up, functional exercises, and group-based motor games focused on locomotor, balance, and ball skills; included peer teaching elements and collaborative tasks	Test of Gross Motor Development – 3rd edition (TGMD-3) – Social Skills Rating System – Parent Form (SSRS-PF) – Friendship Activity Scale (FAS) – Adjective Checklist (ACL) – Semi-structured interviews (parents, teachers, TD peers)	The program enhanced motor skills and social interactions in children with ASD and improved peer attitudes qualitatively. Typically developing students also showed improved physical skills and reduced fear toward ASD peers.
Gianpiero Greco & Roberto De Ronzi / Journal of Physical Education and Sport / 2020	28 children with ASD (ASD); aged 8–11 years ; 24 boys and 4 girls	Randomized Controlled Trial (RCT); pre-test/post-test design	To examine the effect of a 12-week karate training (Kata techniques) on social-emotional and executive functioning in children with ASD	Social skills, problem behaviors, executive functioning (behavioral, emotional, and cognitive regulation)	Yes; waitlist control group with no intervention	12 weeks – Frequency: 2 sessions/week – Duration: 45 minutes/session (24 sessions total)	Shotokan karate (Heian Shodan Kata) targeting physical, social, and cognitive skills, delivered by trained instructors with TD peer support.	– Social Skills Improvement System Rating Scale (SSIS-RS) – Behavior Rating Inventory of Executive Function (BRIEF)	The karate program led to improvements in communication, cooperation, and executive functioning. It also reduced behavioral problems such as hyperactivity, anxiety, and emotional dysregulation.
Kelong Cai et al. / Brain Sciences / 2020	29 children with ASD (ASD); aged 3–6 years	Quasi-experimental study; pre-test/post-test with control group	To investigate the effects of a 12-week mini-basketball training program (MBTP) on social communication skills and white matter integrity in children with ASD	Social communication impairments, white matter integrity (WMI)	Yes; continued usual care (Applied Behavior Analysis) without exercise	12 weeks Frequency: 5 sessions/week Duration: 40 minutes/session	Mini-basketball training including warm-up, skill development, peer interaction, and structured basketball games, implemented alongside usual care	– Social Responsiveness Scale-2 (SRS-2) – Diffusion Tensor Imaging (DTI): Fractional Anisotropy (FA), Mean Diffusivity (MD)	The program improved social communication and enhanced white matter integrity in brain regions related to social and motor function. Changes in brain structure were linked to behavioral improvements.

3.3. Effects of Exercise on Emotional Regulation

Evidence from the two included studies demonstrated a consistent trend favoring impaired emotion regulation in the ASD group. Lee (2024) reported that the ASD cohort (n=23, Mean=62.52, SD=19.78) scored lower on the ERQ than the TD control group (n=22, Mean=73.42, SD=20.13), yielding an SMD of −0.54 (95% CI: −1.13 to 0.06), suggesting a moderate, non-significant impairment. This directional finding was mirrored by Sansi (2021), whose ASD group (n=14, Mean=66.4, SD=7.4) scored lower than their TD counterparts (n=14, Mean=73.1, SD=8.8), resulting in a medium-to-large, statistically significant SMD of −0.80 (95% CI: −1.57 to −0.03). The pooled analysis, weighted at 62.8% for Lee (2024) and 37.2% for Sansi (2021), revealed exceptional consistency between the two data sets. Statistical heterogeneity was negligible (Tau^2=0.00; I^2=0%; Chi^2= 0.28; P=0.60), confirming a high degree of homogeneity and validating the suitability of a quantitative synthesis (Fig 1-2). The combined effect size demonstrated a medium, statistically significant deficit in ERQ performance for children with ASD. The overall pooled SMD was calculated as −0.64, with the test for overall effect confirming significance (Z=2.63, P=0.008). The significant difference observed between ASD and TD groups strongly supports the need to target this area therapeutically. The finding that 25% of the exercise intervention studies reported enhancements in emotion regulation is particularly relevant, as it suggests structured physical activity may be an effective pathway for mitigating this core ASD challenge.

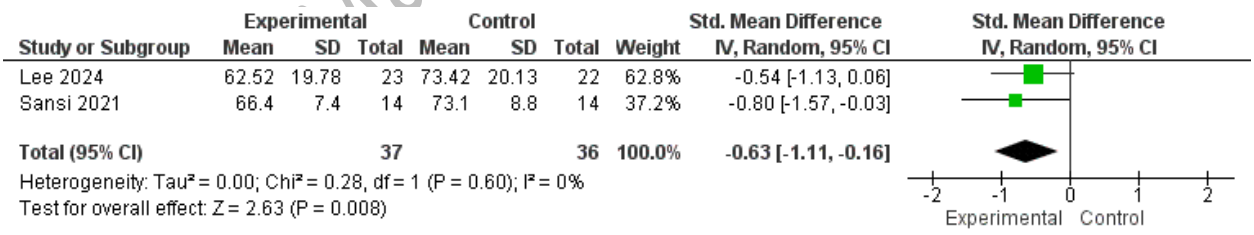

Fig 1.

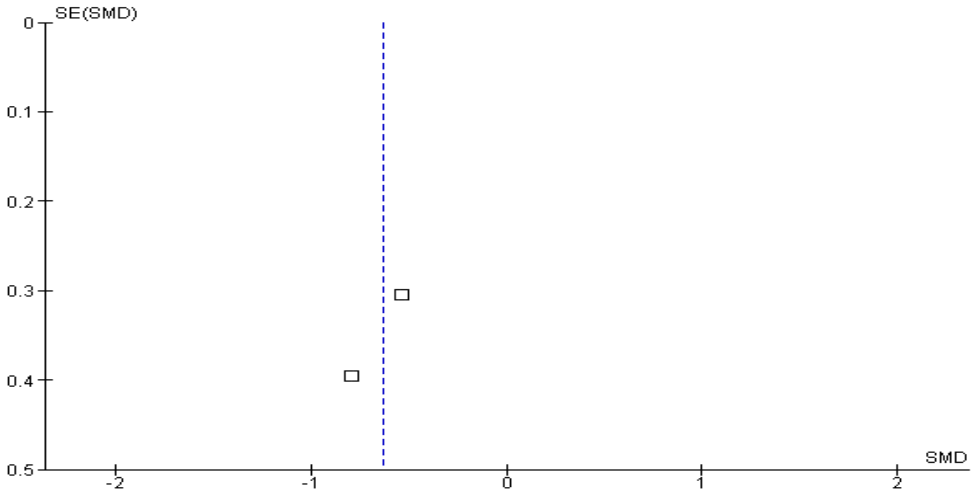

Fig 2.

3.4. Effects of Exercise on Social Skills

The pooled analysis of 13 studies examined the effects of exercise-based interventions on the social skills of children with ASD compared to control conditions (e.g., standard care, non-exercise activities, or waitlist controls). The random-effects model yielded a small, non-significant overall effect size favoring the exercise interventions (SMD = 0.16, 95% CI [–0.47, 0.80], p = 0.62). Between-study variability was notably high (I^2 = 87%, χ^2 = 92.44, p < 0.00001), indicating substantial heterogeneity across studies in design, intervention type, and measurement outcomes. Despite the absence of a statistically significant pooled effect, several individual studies (e.g., Cui 2023, Qi 2024) demonstrated moderate positive improvements in social engagement and communication domains following structured physical activity programs (Fig.3).

The heterogeneity mainly arises from differences in study design, intervention duration, and assessment tools. In particular, Lopez-Diaz (2021) and Wen & Wu (2025) contributed disproportionately to the observed heterogeneity, reflecting variability in sample characteristics and non-standardized outcome measures (Fig.4). Overall, while exercise interventions show promise for improving social functioning among children with ASD, caution is warranted in generalizing these findings due to between-study inconsistencies and methodological diversity. Future trials should ensure standardized outcome measurement and longer follow-up periods to clarify the durability and strength of these effects. Evidence regarding anxiety remains preliminary due to the limited number of studies.

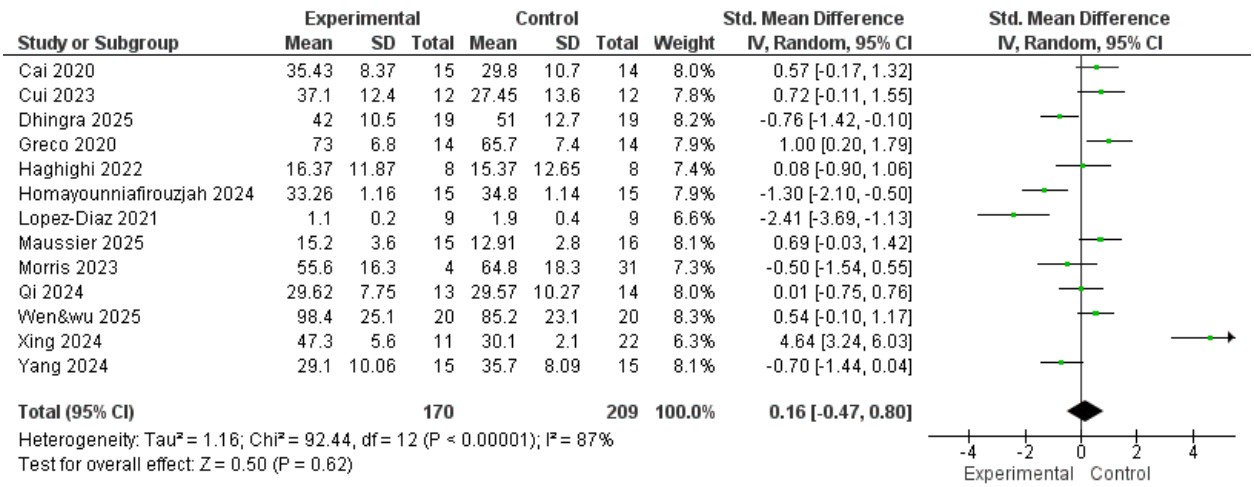

Fig 3.

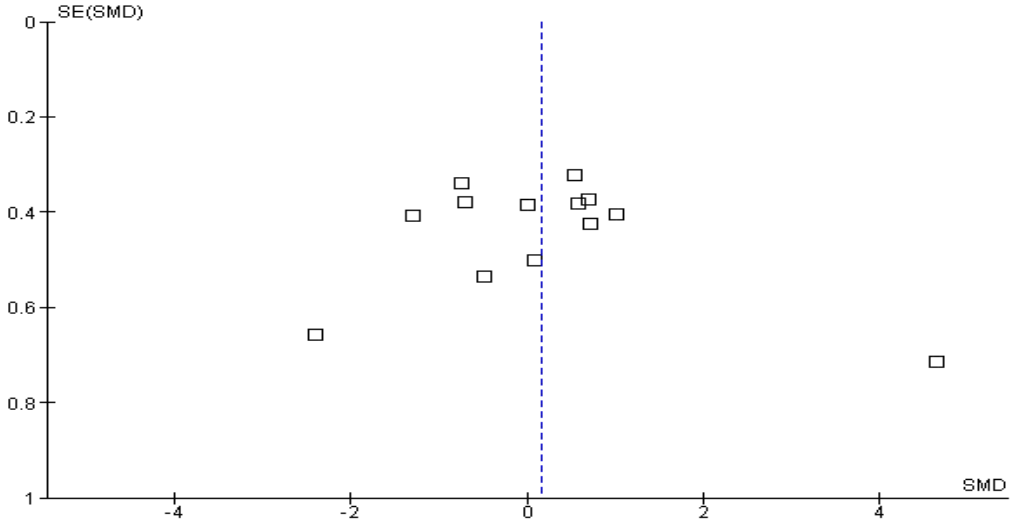

Fig 4.

Discussion

The aim of this systematic review was to examine the effects of exercise interventions on three key domains, emotion regulation, anxiety, and social skills, in children with ASD. Across 16 included studies, the findings consistently indicated that structured physical activity can significantly influence all three domains Notably, nine studies focused specifically on social skills, reporting that group-based activities such as martial arts, football, basketball, and dance contributed to enhanced peer interactions and increased social participation. Notably, nine studies focused specifically on social skills, reporting that group-based activities such as martial arts,

football, basketball, and dance contributed to enhanced peer interactions and increased social participation.

Evidence showed that structured exercise interventions exerted the strongest impact on social skills compared with other domains. Martial arts programs, including judo and karate, implemented in inclusive school environments with the support of trained coaches and psychologists, provided safe opportunities for social engagement and led to significant improvements in social indicators. For example, studies reported improvements of 25.12% in social interaction, 17.72% in communication, and a 21.99% reduction in stereotypical or aggressive behaviors (25). These findings highlight that martial arts not only enhance social cohesion but also foster tolerance and self-discipline in peer interactions (26-28). Similarly, dance-based programs utilizing rhythm, imitation, and movement synchrony improved empathy and communication without requiring substantial changes to educational or family environments (29). Sensorimotor integration training also improved self-confidence and intrinsic motivation for social interaction, with post-test results showing significant gains in social skills compared with control groups (30). These activities provided children with a sense of accomplishment and self-efficacy, reinforcing skills such as cooperation, self-control, and peer communication (31). Game-based programs such as mini-basketball further promoted group interaction and were linked to measurable neurological changes, which correlated positively with improved social communication (32, 33). Collectively, these findings support the notion that physical activity enhances social functioning not only through behavioral pathways but also via neurobiological reorganization.

The review also identified notable effects of exercise on reducing anxiety. Aerobic training significantly reduced SCARED scores in intervention groups, reflecting substantial reductions in anxiety symptoms (34). These improvements were reinforced by biological mechanisms, including reduced cortisol secretion and increased β-endorphin and norepinephrine release, all of which contribute to relaxation and mood regulation (18, 35, 36). Similar findings were reported by Jin et al (2022), who observed that although both exercise and sedentary activities reduced anxiety, only exercise sustained these effects at 12- and 16-week follow-ups (37).

However, it should be noted that only a small proportion of the included studies (18.8%) specifically examined anxiety outcomes. Therefore, conclusions regarding the anxiolytic effects of exercise should be interpreted with caution and may be considered tentative rather than definitive. This suggests that exercise produces durable anxiolytic effects, likely mediated by

improved sleep quality, HPA axis regulation, and gradual reductions in salivary cortisol (38, 39). Martial arts, such as karate, also demonstrated significant anxiolytic effects, likely due to their mind–body nature, which integrates controlled movements, focus, and rhythm to simultaneously engage cognitive and emotional systems (26, 40).

In terms of emotion regulation, the evidence showed multiple pathways through which exercise can be effective. Cycling interventions, both skill-based and stationary, significantly enhanced self-regulation, mediated by improvements in physical self-efficacy and perceived fitness (41). Researchers emphasized that complex tasks involving balance, impulse control, and adherence to instructions activate executive networks, thereby strengthening emotion regulation findings consistent with prior evidence on cognitively engaging exercises (42-43). Sensorimotor integration training also improved self-confidence and intrinsic motivation for social interaction, with post-test results showing significant gains in social skills compared with control groups (30). These improvements were associated with enhanced self-esteem, intrinsic motivation, mood regulation, and attention control. Martial arts interventions such as judo and karate also reduced behavioral problems, improved tolerance, and fostered self-control, supported by structured training environments and professional supervision. These findings align with earlier studies demonstrating the role of martial arts in reducing aggression and improving emotional regulation (25, 44). However, it should be noted that only 25% of the included studies directly assessed emotion regulation outcomes, and most relied on indirect or subjective measures. Therefore, the observed effects on emotion regulation should be interpreted with caution and considered preliminary rather than definitive.

Despite these valuable contributions, the results of this review should be interpreted with caution. Many included studies were limited by small and heterogeneous samples, restricting the generalizability of findings. Variability in the type, intensity, duration, and setting of interventions also complicated direct comparisons. Furthermore, outcome assessments often relied on parent or teacher reports, which may introduce bias. The absence of matched control groups and randomized designs in some studies reduced the causal validity of results, and the lack of long-term follow-ups prevented assessment of intervention sustainability. Additionally, geographic and cultural concentrations of studies limit the applicability of findings to broader populations. These limitations highlight the need for future research with larger sample sizes, more rigorous randomized controlled designs, and cross-cultural contexts to strengthen external validity.

Nevertheless, the practical implications of these findings are noteworthy. Structured exercise programs can serve as complementary, low-cost strategies to enhance social skills, reduce anxiety, and improve emotion regulation in children with ASD. Implementing such programs in schools and rehabilitation centers can provide safe, motivating environments for socio-emotional development. Future steps should include large-scale randomized controlled trials, evaluations of long-term effects, and comparative analyses of different exercise modalities in terms of intensity, duration, and cultural adaptability. Moreover, incorporating neurobiological measures alongside behavioral assessments will enable a more comprehensive understanding of the interplay between exercise, brain function, and behavior. Ultimately, developing culturally tailored and resource-sensitive exercise programs can bridge the gap between research evidence and practical, policy-driven interventions.

Conclusion

Collectively, the evidence indicates that structured exercise interventions may benefit children with ASD, though the strength and consistency of effects vary across outcomes. Current evidence is constrained by substantial heterogeneity in social skills studies, which precluded meaningful subgroup analysis, and the paucity of trials measuring anxiety outcomes. Despite these limitations, the identified baseline deficit in emotion regulation highlights a clear therapeutic need, with several studies reporting post-intervention improvements. Future research should prioritize standardized outcome measures, longer follow-up periods, and targeted trials to clarify the role of exercise in addressing emotional and social challenges in ASD.

Ethical Considerations

Compliance with ethical guidelines

As a meta-analysis utilizing exclusively previously published and aggregated data, this study did not require ethics committee approval or informed consent.

Funding

This study was not supported by any financial resources from public, private, or non-profit organizations.

Authors' contributions

Mahrokh Dehghani: Conceptualization, Methodology, Data Curation, Writing–Original Draft, Supervision. Mojtaba Qasemi and Ebrahim Piri: Investigation, Formal Analysis. Farhad

Rezazadeh: Validation, Resources, Visualization, Writing – Review & Editing (final version). Hosein Safajou: Project Administration, Resources.

Ethical Statement

This study is a systematic review based on previously published research and did not involve any experiments on human participants or animals. Therefore, ethical approval was not required.

Conflict of interest

Authors declare no conflict of interests.

Acknowledgments

The authors sincerely thank all researchers whose studies contributed to this systematic review and provided valuable insights into the effects of exercise interventions on psychosocial outcomes in children with autism spectrum disorder. The authors also appreciate the academic and institutional support that facilitated access to databases and resources essential for conducting this research.

References

1. Bandyopadhyay Prasanta S, Forster Malcolm R, Oxford E, Barkow Jerome H, Leda C, John T, et al. American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders: Dsm-5, Washington, DC, American Psychiatric Publishing, 2013. Ananth Mahesh, In defense of an evolutionary concept of health nature, norms, and human biology, Aldershot, England, Ashgate. Philosophy. 2014;39(6):683-724.
2. Hatipoğlu Özcan G, Özer DF, Pınar S. Effects of motor intervention program on academic skills, motor skills and social skills in children with autism spectrum disorder. Journal of Autism and Developmental Disorders. 2025;55(8):2628-42.
3. Teitelbaum P, Teitelbaum O, Nye J, Fryman J, Maurer RG. Movement analysis in infancy may be useful for early diagnosis of autism. Proceedings of the National Academy of Sciences. 1998;95(23):13982-7.
4. Ozonoff S, Young GS, Goldring S, Greiss-Hess L, Herrera AM, Steele J, et al. Gross motor development, movement abnormalities, and early identification of autism. Journal of autism and developmental disorders. 2008;38(4):644-56.
5. Özcan GH, Özer D, Pınar S. An Analysis of the Gross Motor Skills of Children Aged 3-6 Years With Autism Spectrum Disorder in Comparison with Their Typically Developing Peers. Palaestra. 2023;37(1).
6. Busti Ceccarelli S, Ferrante C, Gazzola E, Marzocchi GM, Nobile M, Molteni M, et al. Fundamental motor skills intervention for children with autism spectrum disorder: A 10-year narrative review. Children. 2020;7(11):250.
7. Odeh CE, Gladfelter AL, Stoesser C, Roth S. Comprehensive motor skills assessment in children with autism spectrum disorder yields global deficits. International Journal of Developmental Disabilities. 2022;68(3):290-300.
8. Scattone D. Social skills interventions for children with autism. Psychology in the Schools. 2007;44(7):717-26.
9. Wang LA, Petrulla V, Zampella CJ, Waller R, Schultz RT. Gross motor impairment and its relation to social skills in autism spectrum disorder: A systematic review and two meta-analyses. Psychological bulletin. 2022;148(3-4):273.
10. Ohara R, Kanejima Y, Kitamura M, P. Izawa K. Association between social skills and motor skills in individuals with autism spectrum disorder: a systematic review. European journal of investigation in health, psychology and education. 2019;10(1):276-96.
11. Lloyd M. Fundamental Motor Skill Interventions for Children with Autism Spectrum Disorder. Disability and Motor Behavior: A Handbook of Research. 2023:49.
12. Tse CYA, Lee HP, Chan KSK, Edgar VB, Wilkinson-Smith A, Lai WHE. Examining the impact of physical activity on sleep quality and executive functions in children with autism spectrum disorder: A randomized controlled trial. Autism. 2019;23(7):1699-710.
13. Diamond A, Ling DS. Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. Developmental cognitive neuroscience. 2016;18:34-48.

14. White SW, Oswald D, Ollendick T, Scahill L. Anxiety in children and adolescents with autism spectrum disorders. Clinical psychology review. 2009;29(3):216-29.
15. Gillott A, Furniss F, Walter A. Anxiety in high-functioning children with autism. Autism. 2001;5(3):277-86.
16. Mitchell P, Sheppard E, Cassidy S. Autism and the double empathy problem: Implications for development and mental health. British Journal of Developmental Psychology. 2021;39(1):1-18.
17. DeBoer LB, Powers MB, Utschig AC, Otto MW, Smits JA. Exploring exercise as an avenue for the treatment of anxiety disorders. Expert review of neurotherapeutics. 2012;12(8):1011-22.
18. Broman-Fulks JJ, Berman ME, Rabian BA, Webster MJ. Effects of aerobic exercise on anxiety sensitivity. Behaviour research and therapy. 2004;42(2):125-36.
19. Adams D, Clark M, Keen D. Using self-report to explore the relationship between anxiety and quality of life in children on the autism spectrum. Autism Research. 2019;12(10):1505-15.
20. Trembath D, Germano C, Johanson G, Dissanayake C. The experience of anxiety in young adults with autism spectrum disorders. Focus on Autism and Other Developmental Disabilities. 2012;27(4):213-24.
21. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. bmj. 2021;372.
22. Yamada T, Kondo Y, Momosaki R. PICO and Risk Of bias Navigator for Evidence Based Medicine. PeerJ Preprints. 2019.
23. Wilson B, Bialocerkowski A. The effects of Kinesiotape applied to the lateral aspect of the ankle: relevance to ankle sprains–a systematic review. PloS one. 2015;10(6):e0124214.
24. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. Physical therapy. 2003;83(8):713-21.
25. Maussier N, Pierantozzi E, Manno R, Magnanini A. Judo and karate in primary school as a means for the improvement of social inclusion for autistic children. Sport Sciences for Health. 2025:1-8.
26. Bahrami F, Movahedi A, Marandi SM, Abedi A. Kata techniques training consistently decreases stereotypy in children with autism spectrum disorder. Research in developmental disabilities. 2012;33(4):1183-93.
27. Bahrami F, Movahedi A, Marandi SM, Sorensen C. The effect of karate techniques training on communication deficit of children with autism spectrum disorders. Journal of autism and developmental disorders. 2016;46(3):978-86.
28. Ferreira JP, Ghiarone T, Cabral Junior CR, Furtado GE, Moreira Carvalho H, Machado-Rodrigues AM, et al. Effects of physical exercise on the stereotyped behavior of children with autism spectrum disorders. Medicina. 2019;55(10):685.
29. Morris PO, Hope E, Foulsham T, Mills JP. Exploring the use of a dance-based exergame to enhance autistic children's social communication skills in the home and school environments: a feasibility study. International Journal of Developmental Disabilities. 2025;71(1):141-58.

30. Homayounnia Firouzjah M, Majidi Yaeichi N, Hematinia R. The effectiveness of sensory-motor integration exercises on social skills and motor performance in children with autism. Journal of autism and Developmental Disorders. 2025;55(5):1902-9.
31. Zaragas H, Fragkomichelaki O, Geitona M, Sofologi M, Papantoniou G, Sarris D, et al. The effects of physical activity in children and adolescents with developmental coordination disorder. Neurology international. 2023;15(3):804-20.
32. Yang Y, Chen D, Cai K, Zhu L, Shi Y, Dong X, et al. Effects of mini-basketball training program on social communication impairments and regional homogeneity of brain functions in preschool children with autism spectrum disorder. BMC Sports Science, Medicine and Rehabilitation. 2024;16(1):92.
33. Wang J-G, Cai K-L, Liu Z-M, Herold F, Zou L, Zhu L-N, et al. Effects of mini-basketball training program on executive functions and core symptoms among preschool children with autism spectrum disorders. Brain sciences. 2020;10(5):263.
34. DHINGRA A, GUPTA A. Effect of Aerobic Training on Anxiety, Activities of Daily Living and Visual Motor Skills Performance in Children with Autism: A Randomised Controlled Trial. Journal of Clinical & Diagnostic Research. 2025;19(2).
35. Hillier A, Murphy D, Ferrara C. A pilot study: Short-term reduction in salivary cortisol following low level physical exercise and relaxation among adolescents and young adults on the autism spectrum. Stress and Health. 2011;27(5):395-402.
36. REZVANKHAH GN, EMAMI HSA. Effect of selected spark motor program on anxiety of children with Asperger. 2015.
37. Gehricke J-G, Lowery LA, Alejo SD, Dawson M, Chan J, Parker RA, et al. The effects of a physical exercise program, LEGOR and Minecraft activities on anxiety in underserved children with autism spectrum disorder. Research in Autism Spectrum Disorders. 2022;97:102005.
38. Calhoun SL, Fernandez-Mendoza J, Vgontzas AN, Liao D, Bixler EO. Prevalence of insomnia symptoms in a general population sample of young children and preadolescents: gender effects. Sleep medicine. 2014;15(1):91-5.
39. Goldman SE, Richdale AL, Clemons T, Malow BA. Parental sleep concerns in autism spectrum disorders: variations from childhood to adolescence. Journal of autism and developmental disorders. 2012;42(4):531-8.
40. Movahedi A, Bahrami F, Marandi SM, Abedi A. Improvement in social dysfunction of children with autism spectrum disorder following long term Kata techniques training. Research in Autism Spectrum Disorders. 2013;7(9):1054-61.
41. Tse AC, Liu VH, Lee PH, Anderson DI, Lakes KD. The relationships among executive functions, self-regulation, and physical exercise in children with autism spectrum disorder. Autism. 2024;28(2):327-41.
42. Diamond A. Activities and programs that improve children's executive functions. Current directions in psychological science. 2012;21(5):335-41.
43. Tomporowski PD, Pesce C. Exercise, sports, and performance arts benefit cognition via a common process. Psychological bulletin. 2019;145(9):929.

44. Morales Aznar J, Pierantozzi E, Fukuda DH, Garcia V, Guerra Balic M, Sevilla-Sánchez M, et al. Improving motor skills and psychosocial behaviors in children with autism spectrum disorder through an adapted judo program. Frontiers in Physiology, 2021, 12: 712471.