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REVIEW PAPER

Effects of Physical Education on Socializing and Communicating Among Children and Preadolescents with Autism Spectrum Disorder: a Systematic Review and Meta-Analysis

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Abstract

Physical education stimulates brain plasticity. However, the effect of physical education interventions on socialization and communication skills in children and preadolescents with autism spectrum disorder is unknown. To review and qualitatively describe studies published between 2012 and 2022 that intervened with physical education to generate changes in socialization and communication skills in children and preadolescents with autism spectrum disorder. The search was designed following the PRISMA® guidelines for systematic reviews and meta-analyses and performed in Web of Science, Scopus, and PubMed between 2012 and 2022. Fourteen studies were included in the systematic review and nine in the meta-analysis. Physical education was shown to be effective in increasing socialization and communication skills in children and preadolescents with autism spectrum disorder.

Keywords Physical education · Autism spectrum disorder · Socializing · Communicating among · Children · Preadolescents

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Autism spectrum disorder (ASD) is a diverse group of conditions related to brain development (World Health Organization, 2023). The ASD until the *Diagnostic and Statistical Manual of Mental Disorders 4th edition (DSM-IV)* was established as a heterogeneous condition that varied in severity and clinical diagnosis, from a mild form, such as Asperger's syndrome, to more severe forms, such as childhood disintegrative disorder or Rett's disorder, that require constant support (Rosen et al., 2021). As of DSM 5th edition (DSM-V), features previously associated with Asperger syndrome are now considered part of the spectrum of ASD (Edelson, 2022). This means that people previously diagnosed with Asperger syndrome could now be diagnosed with ASD (Smith & Jones, 2020). In contrast, Rett syndrome is now considered a separate disorder within the category of neurodevelopmental disorders rather than being part of the spectrum of ASD (Spagnoli et al., 2021). Individuals with ASD present a neurodevelopmental disorder characterized by difficulties in communication, social interaction, and repetitive and restricted behaviors, among other conditions (Baio, 2014). They may also show difficulties understanding social norms and nonverbal cues, leading to difficulties in relationships with the environment (Lai et al.,

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2020). In addition, individuals with ASD may show intense and restricted interests through repetitive and stereotyped behaviors, such as the need to follow specific routines and patterns (Bishop-Fitzpatrick et al., 2018). It has been shown that ASD can manifest as early as infancy, while its diagnosis can be made as early as 2–3 years of age (Zwaigenbaum et al., 2015). In addition, the scarcity of validated instruments for specific populations further complicates diagnosing and treating individuals with ASD (Bishop & Lord, 2023). Some risk factors involved in the development of ASD are genetic, environmental, and neurobiological (Estes & McAllister, 2016). Treatment of ASD is based on a multidisciplinary approach that includes behavioral, educational, and medical interventions and should be tailored to each person's needs (Lai et al., 2021).

In recent years, a significant increase in the average prevalence of ASD has been observed worldwide (World Health Organization, 2023; Zeidan et al., 2022). In this regard, recent research reports that 100 out of every 10,000 people have some of the characteristics of ASD (Zeidan et al., 2022). Another epidemiological background to consider is the prevalence of more males than females diagnosed with ASD; eventually, this phenomenon may be explained by the "female protective effect" or by the "camouflage component" that females develop (Hull et al., 2020). In addition, the World Health Organization (WHO) reported that it does not know the exact prevalence of ASD in low- and middle-income countries (World Health Organization, 2023). However, it is speculated that the number of people with ASD in nations on the African and Asian continents (countries lacking support from medical or educational systems) may be significantly higher than the known figures (Hossain et al., 2017; Mpaka et al., 2016). These figures illustrate that ASD heavily burdens community health systems worldwide (Salari et al., 2022).

As mentioned above, individuals diagnosed with ASD have deficits in social communication, including deficits in social-emotional reciprocity and nonverbal communication behaviors, as well as in developing, maintaining, and understanding interpersonal relationships (Müller & Fishman, 2018). In this context, non-pharmacological treatments appear to be a promising option for treating the conditions of people with ASD (Bharathi et al., 2019; S. A. Green et al., 2015; Miyazaki et al., 2015; Perihan et al., 2020; Tao et al., 2021). For example, mindfulness (Tao et al., 2021), music therapy (Bharathi et al., 2019), and cognitive-behavioral therapy (Perihan et al., 2020) have improved motor, sensory, and emotional skills, attention, social functioning, and quality of life in children and preadolescents with ASD. However, some of these treatments may have limitations, such as high financial cost or adverse effects, such as hypersensitivity to sounds and headaches because of music therapy (S. A. Green et al., 2015); if animals are used, allergic reactions may occur (Miyazaki et al., 2015).

Another non-pharmacological treatment is physical education (PE). PE is a subject within the school curriculum and encompasses a set of disciplines and exercises that pursue the objective of achieving the integral development of individuals. PE can also be developed in parallel to the school program. Among other aspects, PE includes physical activity, physical exercises, and sports that contribute to a person's physical, mental, and social development. It is irrefutable that PE has a positive impact on the motor development of children and preadolescents (Huang et al., 2020), as well as increases socialization and communication in children and preadolescents with ASD (Haghighi et al., 2022; Huang et al., 2020; Hynes & Block, 2022). Specifically, physical exercise has been shown to increase brain activity, favoring the development of brain plasticity (Chen et al., 2016), autonomic balance, function, and the structure of brain social networks (Ludyga et al., 2022); changes that could favor social communication in people diagnosed with ASD (Müller & Fishman, 2018).

So far, it has been shown that lower fine motor skills were associated with greater social communication deficits and greater severity of ASD (Zhou et al., 2022). Proper physical stimulation through PE promotes brain plasticity and, thus, brain social networks in children and preadolescents with ASD (Chen et al., 2016; Ludyga et al., 2022). This implies the development of socialization and communication (Hynes & Block, 2022). However, to our knowledge, during this decade, no research has qualitatively described and calculated the effect size (ES) of interventions with PE to favor socialization and communication skills in children and preadolescents with ASD (Huang et al., 2020). Consequently, the primary objective of this systematic review and meta-analysis was to update, review, and qualitatively describe studies published between 2012 and 2022 that intervened with PE, in its broad spectrum, to generate changes in socialization and communication skills in children and preadolescents with ASD, while the secondary objective was to calculate the ES of the different interventions in the selected studies.

Materials and Methods

The literature search followed the guidelines for systematic reviews and meta-analysis (PRISMA®) (Page et al., 2021) and the Cochrane Collaboration guidelines to evaluate the risk of study bias. The protocol of this review was registered in PROSPERO (CRD42023394185).

Eligibility Criteria

The literature search followed the guidelines for systematic reviews and meta-analysis (PRISMA®) (Page et al., 2021).

For this purpose, population (i), intervention (ii), comparators (iii), outcomes (iv), and study design (v) (PICOS) were established as follows: (i) children and preadolescents diagnosed with ASD through clinical assessment, between 4 and 14 years old; (ii) studies that included intervention with PE (physical activity, physical exercise, or sports programs); (iii) control group (CG) that did not have training programs or experimental group (EG) with pre-test and post-test; (iv) psychosocial variables of socialization or communication; (v) the systematic review included studies with pre-experimental (only with EG) and quasi-experimental design (EG and CG with pre-test and post-test), while the meta-analysis only considered randomized controlled trials with EG and CG (Bucker et al., 1997). The studies that failed to fulfill the inclusion criteria were not considered in the systematic review or the meta-analysis. Possible discrepancies were resolved through discussion until a consensus was reached.

Information Sources and Search

A thorough electronic search was conducted in several databases and search engines to perform this review. Articles published in the Web of Science (WoS), Scopus, and PubMed, published in English, were included. A search range was established from January 2012 to December 2022. In each database, the search included hits in the title, abstract, and keywords search fields. The following keywords were combined with Boolean operators AND/OR: [("physical education") AND ("socialization" OR "integration") AND ("autism spectrum disorder" OR "Asperger" OR "continuing educational needs") AND ("children" OR "schoolchildren" OR "childhood")]. One of the authors performed the search, and two reviewed the studies. Together, they decided whether the studies were appropriate for inclusion.

Data Extraction

The data collected were author, year, journal, target, sample, number of participants, age, dependent and independent variable, treatment, outcomes, performance, experimental, and control groups. One reviewer extracted the continuous data for the systematic review and meta-analysis; a second verified them. Disagreements were resolved through discussion. The values were entered in a spreadsheet in the Excel software, and then the Review Manager software was used (version 5.4).

Risk of Publication Bias Between Studies

The risk of publication bias between studies was only carried out in those parts of the meta-analysis. Publication bias was assessed using Egger's statistical test. This test determined the presence of bias at $p \leq 0.05$ (Egger et al., 1997). Funnel plots were created to interpret the general effect, followed by an Egger's statistic to confirm or refute publication bias.

Methodological Quality and Risk of Bias of Individual Studies

The methodological quality and risk of bias of each study selected for the meta-analysis were evaluated using the Cochrane Collaboration Guide (J. P. T. Higgins et al., 2019). The list was divided into six different domains: selection bias (random sequence generation, allocation concealment), performance bias (blinding of participants and personnel), detection bias (blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective reporting), and other types of bias (declaration of conflict of interest). For each item, the answer to a question was considered; when the question was answered with a "Yes," the bias was low; when it was "No," the bias was high; when it was "Unclear," the possible bias was connected to a lack of information or uncertainty.

Summary Measures and Synthesis of Results in Studies

For the analysis and interpretation of the results, the outcomes used for the systematic review and meta-analysis were (a) socialization and (b) communication. The meta-analysis was performed with studies that included an intervention with PE—physical activity, physical exercise, or sport—containing a CG and an EG and those in which the variables of socialization and/or communication had presented pre- and post-intervention evaluations. Thus, if any study did not meet these characteristics, it could not be part of the meta-analysis and would only be considered part of the systematic review. To evaluate the quality of the experiments and interpret the risk of bias values, Review Manager version 5.4 was used (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). The same software was used for the meta-analysis's descriptive and statistical analysis. To compare the effects of the EG that performed PE versus a CG that contained no intervention, the number of participants, standardized mean difference (SMD), and standard error of SMD were analyzed for each study. Hedges' g test was used to calculate the SMD of each study (Hedges, 1981). The overall effect and the 95% confidence interval (CI) were calculated by weighting the SMD by the inverse of the variance. Additionally, the SMD of both the EG and CG groups were subtracted to obtain the ES, which was used together with the pooled SD of change

to calculate the variance (ES = [mean EG – mean CG]/SD). Cohen's criteria to interpret the ES's magnitude were: < 0.2, trivial; 0.2–0.5, small; 0.5–0.8, moderate; and > 0.8, large (Cohen, 2013).

Due to real heterogeneity rather than chance, the I^2 statistic was calculated to indicate the studies' total observed variation. I^2 values are included from 0 to 100%, representing a small amount of inconsistency (between 25 and 50%), a medium amount of heterogeneity (between 50 and 75%), and a large heterogeneity (when the I^2 value was higher than 75%). In this sense, low, moderate, and high adjectives would be accepted, referring to I^2 values of 25%, 50%, and 75%, respectively, although a restrictive categorization would not be adequate in all circumstances (J. Higgins et al., 2003).

Results

Studies Selection

The literature search through electronic databases identified 302 articles, of which 40 were duplicates. The remaining 262 articles were filtered by title and abstract, and 13 studies remained to be read and analyzed. After a review of those 13 studies, eight were eliminated because they did not meet the inclusion criteria. Ten additional studies were added in the search for articles oriented by bibliographic references. As a result, 15 articles were included in the systematic review. Of these, fifteen did not meet the meta-analysis characteristics. Thus, only nine studies were part of the meta-analysis. The search strategy and study selection are shown in Fig. 1.

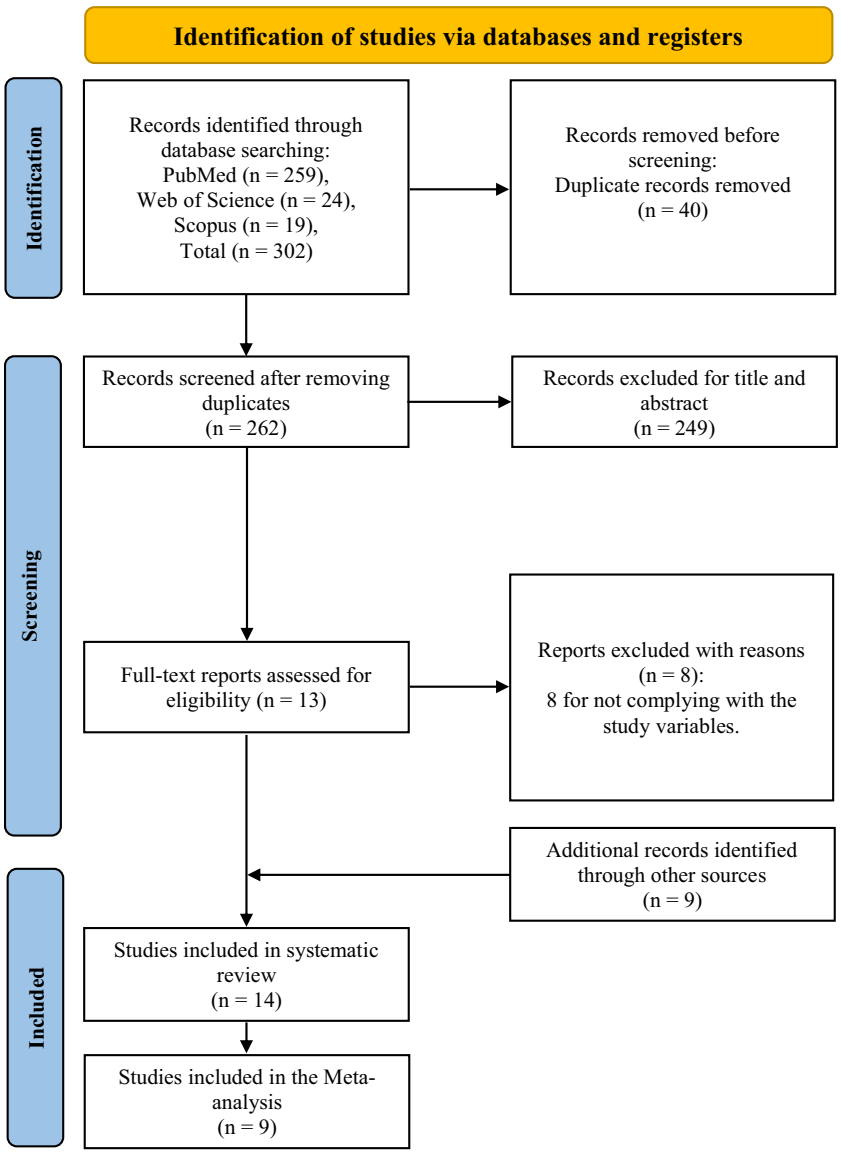

Fig. 1 Search strategy and study selection

Out of 15 studies, 13 considered "socialization" to assess the effect of PE on psychosocial parameters (Bremer et al., 2015; Cai et al., 2020; Chu & Pan, 2012; Guli et al., 2013; Haghighi et al., 2022; Ketcheson et al., 2017; Morales et al., 2021; Movahedi et al., 2013; Mpella et al., 2019; Najafabadi et al., 2018; Sansi et al., 2021; Zanobini & Solari, 2019; Zhao & Chen, 2018), and five used "communication" to evaluate the same effect (Bahrami et al., 2016; Cai et al., 2020; Haghighi et al., 2022; Morales et al., 2021; Zanobini & Solari, 2019) (Table 1).

Assessment of Methodological Quality and Risk of Bias of Individual Studies

The methodological-quality-and-risk-of-bias assessment of the fifteen studies selected for systematic review and meta-analysis resulted as follows. The study developed by Ketcheson et al. (2017), Morales et al. (2021), and Mpella et al. (2019) had a high risk of bias for the domain of selection bias (random sequence generation, allocation concealment), performance bias (blinding of participants and research staff), detection bias (blinding of outcome assessment), and unclear risk for selective reporting (reporting bias). Likewise, all the studies showed a low risk of bias in incomplete outcome data (attrition bias) and other biases. Full details of each study and domain are presented in Figs. 2 and 3.

Meta-Analysis

During the analysis of the selected studies, nine were considered randomized controlled trials with EG and CG, pretest, and post-test (Bahrami et al., 2016; Cai et al., 2020; Chu & Pan, 2012; Guli et al., 2013; Haghighi et al., 2022; Movahedi et al., 2013; Najafabadi et al., 2018; Zanobini & Solari, 2019; Zhao & Chen, 2018). Consequently, these nine studies were meta-analyzed in two outcomes: (a) socialization and (b) communication, both in children and preadolescents diagnosed with ASD. In this analysis, it was also observed that five studies (Cai et al., 2020; Haghighi et al., 2022; Movahedi et al., 2013; Najafabadi et al., 2018; Zanobini & Solari, 2019) evaluated "socialization" with inverse scales (the lower the score, the greater the development of the psychosocial variable), and three studies (Chu & Pan, 2012; Guli et al., 2013; Zhao & Chen, 2018) evaluated with a direct scale (the higher the score, the greater the development of the psychosocial variable). In the case of "communication," only studies evaluated with an inverse scale.

Publication Bias

Publication bias of the nine meta-analyzed studies was assessed using Egger's statistical test. This test determined the presence of bias at $p \leq 0.05$ (Egger et al., 1997). Funnel plots were created to interpret the general effect, followed by an Egger's statistic to confirm or refute publication bias. Egger's analysis suggested that the primary variables did not show publication bias: a, socialization (inverse scale): $z = 3.22$, $p = 0.001$; b, socialization (direct scale): $z = 3.96$, $p < 0.0001$; c, communication: $z = 2.19$, $p = 0.03$ (Fig. 4).

Effect of a PE on Socialization (Inverse Scale)

Five studies were included in this analysis (Cai et al., 2020; Haghighi et al., 2022; Movahedi et al., 2013; Najafabadi et al., 2018; Zanobini & Solari, 2019). However, one included two "socialization" assessments in the study design. For the meta-analysis, the study by Najafabadi et al. (Najafabadi et al., 2018) considered two independent designs (the *Gilliam Autism Rating Scale for "social interaction" and Autism treatment evaluation checklist for "sociability"*). Therefore, six studies with an inverse scale were included in the meta-analysis that estimated the effect of PE on socialization in children and preadolescents with ASD. Figure 5 shows that PE (physical activity, physical exercise, or sport) generates a moderate and significant effect on socialization in children with ASD (SMD, − 0.63; 95% CI − 1.01 to − 0.25; $p = 0.001$). The meta-analysis showed a small inconsistency among the reviewed studies ($I^2 = 22\%$; $p = 0.27$). However, five studies stated that PE benefits children and preadolescents with ASD, improving their socialization (Cai et al., 2020; Movahedi et al., 2013; Najafabadi et al., 2018; Zanobini & Solari, 2019). Only the study of Haghighi et al. (2022) showed a neutral effect for this psychosocial variable.

Effect of a PE on Socialization (Direct Scale)

Three studies were included in this analysis (Chu & Pan, 2012; Guli et al., 2013; Zhao & Chen, 2018). However, two included two "socialization" assessments in the study design (Chu & Pan, 2012; Guli et al., 2013). In this regard, the test used by Chu and Pan (2012) to assess "socialization" in children and adolescents with ASD (*Computerized Evaluation Protocol of Interactions in Physical Education*) considers two subscales: (1) "Social interactions with a trained peer or sibling," and (2) "Social interactions with a teacher;" in turn, each subscale assesses three secondary outcomes: (a) social interactions with a trained peer or sibling, (b) social interactions with a teacher, and (c) social interactions with a child with ASD. Therefore, nine studies with direct scaling were included in the meta-analysis that estimated the effect of PE on socialization in children and preadolescents with ASD. Figure 6 shows that PE (physical activity, physical exercise, or sport) generates a moderate and significant effect on socialization in children with ASD (SMD, 0.63; 95% CI 0.32–0.94; $p < 0.0001$). The

Table 1 Characteristics of the studies included in the systematic review and meta-analysis

Authors	Title	Objective	Participants	Dependent variable	Independent variable	Treatment	Outcome	Effect
Bahrami et al. (2016)	The effect of karate techniques training on communication deficit of children with ASD	To examine the long-term effect of karate techniques training on the communication of children with ASD	EG ASD: $n=15$ Age: 9.2 ± 3.3 years CG ASD: $n=15$ Age: 9.0 ± 3.3 years	Communication deficit	Karate techniques training	14 weeks (56 sessions) of karate techniques training (Heian Shodan Kata)	GARS-2 (pre-test and post-test comparison): $p < 0.001$	Communication ↑
Bremer et al. (2015)	Effectiveness of a fundamental motor skill intervention for 4-year-old children with autism spectrum disorder: A pilot study	To investigate the effectiveness of an FMS intervention in improving the motor skills, adaptive behavior, and social skills of 4-year-old children with ASD	EG ASD: $n=5$ Age: 4.3 ± 0.2 years CG ASD: $n=4$ Age: 4.3 ± 0.2 years	Motor proficiency, adaptive behavior, social skills	FMS intervention	EG: attended a 12-week FMS intervention for one h per week	SSIS (pre-test and post-test comparison): social skills standard score $p=0.783$ Problem behavior standard score $p=0.855$	Socialization ↔
Cai et al. (2020)	Mini-Basketball Training Program Improves Physical Fitness and Social Communication in Preschool Children with ASD	To examine the effects of a 12-week MBTP on physical fitness and social communication in preschool children with ASD	EG ASD: $n=15$ Age: 5.0 ± 0.6 years CG ASD: $n=15$ Age: 4.5 ± 0.8 years	Physical fitness and social communication	MBTP intervention	MBTP: one session per day, five days per week for 12 consecutive weeks (60 sessions in total)	SRS-2 (pre-test and post-test comparison): $p > 0.05$ Social awareness $p > 0.05$ Social cognition $p > 0.05$ Social communication $p > 0.05$ Social motivation $p > 0.05$ Autistic mannerisms $p > 0.05$	Socialization ↔ Communication ↑

Table 1 (continued)

Authors	Title	Objective	Participants	Dependent variable	Independent variable	Treatment	Outcome	Effect
Chu and Pan (2012)	The effect of peer- and sibling-assisted aquatic programs on interaction behaviors and aquatic skills of children with ASD and their peers/siblings	To assess the effect of peer- and sibling-assisted learning on interaction behaviors and aquatic skills in children with ASD	Peer-assisted group: $n=14$ (ASD = 7; TD peer = 7) Age: 8.5 ± 1.6 and 7.1 ± 1.0 years Sibling-assisted group: $n=14$ (ASD = 7; TD sibling = 7) Age: 8.3 ± 1.5 and 7.3 ± 2.4 years CG: $n=14$ (ASD = 7; TD Control = 7) Age: 9.2 ± 1.4 and 8.6 ± 2.8 years	Physical and social interactions	Peer- and sibling-assisted aquatic program	Two days per week for 16 weeks (32 sessions in total), with three instructional conditions: (a) teacher-directed, (b) peer/sibling-assisted, and (c) voluntary support	CEPI-PE (post-test comparison between peer-assisted, sibling-assisted, and control groups): social interactions with a trained peer or sibling $p < 0.05$ Social interactions with a teacher $p < 0.05$	Socialization ↑
Guli et al. (2013)	SCIP: A pilot study of a creative drama program for youth with social difficulties	To evaluate the efficacy of the full and manualized version of the SCIP	EG ASD: $n=13$ M Age: 11.1 ± 2.1 years CG ASD: $n=15$ M Age: 10.4 ± 1.9 years	Social and behavioral adjustment	Manualized creative drama intervention program designed	16-session manualized intervention program developed from creative drama activities	BASC (pre-test and post-test comparison): withdrawal $p=0.859$ Social skills $p=0.420$ Qualitative findings: Observed positive interactions $p=0.028$ Observed solitary behaviors $p=0.26$	Socialization ↑
Haghighi et al. (2022)	Combined physical training strategies improve the physical fitness, behavior, and social skills of autistic children	To investigate the effects of CPT on physical fitness, stereotyped behaviors, communication, and social interaction in children with ASD	EG ASD: $n=8$ Age: 9.0 ± 1.3 years CG ASD: $n=8$ Age: 8.1 ± 1.3 years	Stereotypic behaviors, communication, social interaction	Combined physical training	CPT: ball game, rhythmic movements, and resistance training (8 weeks, three sessions per week: 10-min warm-up, a 40–60 min duration CPT program, and a 10-min cool-down)	GARS-2 (pre-test and post-test comparison): stereotypic behaviors $p=0.018$ Communication $p=0.043$ Social interaction $p=0.696$	Socialization ↑ Communication ↑

Table 1 (continued)

Authors	Title	Objective	Participants	Dependent variable	Independent variable	Treatment	Outcome	Effect
ketcheson et al. (2017)	The effects of an early motor skill intervention on motor skills, levels of physical activity, and socialization in young children with autism spectrum disorder: A pilot study	To measure the efficacy of an intensive motor skill intervention on motor skills, physical activity, and socialization (between the POPE) in young children with autism spectrum disorder	EG ASD: $n=11$ (M = 9, F = 2) CG ASD: $n=9$ (M = 6, F = 3) Age: 4–6 years	Motor skills, physical activity, and socialization	Physical education class	Intervention: locomotor skills and object control skills (4 h/day, five days per week for eight weeks)	POPE (only EG): Solitary BL = 49.79 ± 6.61 T1 = 38.18 ± 10.17 T2 = 31.97 ± 6.63 T3 = 39.97 ± 7.54 T4 = 18.79 ± 6.93 F: 4, 8.76 $p < 0.01$	Socialization ↑
Morales et al. (2021)	Behavioral improvements in children with autism spectrum disorder after participation in an adapted judo program followed by deleterious effects during the COVID-19 lockdown	To compare the behavioral scores on the six GARS subscales obtained by children with ASD during three different periods (baseline/control, judo intervention, and lockdown)	EG ASD: $n=11$ (M = 7, F = 4) Age: 10.1 ± 2.4 years	Repetitive behaviors, social interaction, social communication, emotional responses, cognitive style, and maladaptive speech	Adapted judo sessions	Eight-week judo intervention (weekly adapted 75-min judo sessions)	GARS-3 scale (between BL, T2, and T3): repetitive behaviors, social interaction, social communication, and emotional responses $p < 0.05$ GARS (between BL, T2, and T3): cognitive style and maladaptive speech $p > 0.05$	Socialization ↑ Communication ↔
Movahedi et al., 2013)	Improvement in social dysfunction of children with ASD following long-term Kata techniques training	To investigate the effects of long-term kata techniques training on the social interaction of children with ASD	EG ASD: $n=13$ Age: 9.5 ± 3.4 years CG ASD: $n=13$ Age: 9.0 ± 3.3 years	Social dysfunction	Exercise kata techniques	Kata techniques instruction: 1 session/day, four days/week for 14 weeks (56 sessions)	GARS-2 (pre-test and post-test comparison): Social interaction $p < 0.001$	Socialization ↑

Table 1 (continued)

Authors	Title	Objective	Participants	Dependent variable	Independent variable	Treatment	Outcome	Effect
Mpella et al. (2019)	The effects of a theatrical play program on social skills development for young children with autism spectrum disorders	To examine the effects of a theatrical play program on social skills development for young children with autism spectrum disorders	EG ASD: $n=6$ (M = 4, F = 2) Age: 10.6 ± 0.7 years	Social skills development	Physical education regular school program	Theatrical play session (16 educational sessions for eight weeks)	COMPASS Social awareness: Cooperation = 2.72 ± 0.64 Obedience = 2.83 ± 0.50 Indifferent = 2.51 ± 0.65 Anxiety = 2.02 ± 0.73	Socialization ↑
Najafabadi et al. (2018)	The effect of SPARK on social and motor skills of children with autism	to evaluate the effectiveness of a selected group exercise known as SPARK on the motor and behavioral skills of children with ASD	EG ASD: $n=12$ Age: 7.0 ± 2.0 years CG ASD: $n=14$ Age: 8.0 ± 2.2 years	Motor and social skills	SPARK program	SPARK program: 36 sessions (3 sessions per week, 40 min per session)	GARS-2 (pre-test and post-test comparison): Social interaction $p=0.01$ ATEC (pre-test and post-test comparison): Sociability $p=0.01$	Socialization ↑
Sansi et al. (2021)	Effects of an inclusive physical activity program on the motor skills, social skills, and attitudes of students with and without ADS	To investigate the effects of an IPA program on the motor skills, social skills, and attitudes of students with and without ASD	EG: $n=27$ (ASD = 13, TD = 14 with TD) GC $n=18$ (ASD = 9, TD = 9) Age: 6–11 years	Social skills	Inclusive physical activities	IPA program activities (1 h a day, two days a week for 12 weeks): (i) immersive motions (5 min) (ii) functional exercises (10 min) (iii) group activities (35 min) (iv) whole group activities (10 min)	SSRS-PF (pre-test and post-test comparison): $p > 0.05$ Responsibility $p > 0.05$ Cooperation $p > 0.05$ Self-control $p > 0.05$ Assertion $p > 0.05$ Externalizing $p > 0.05$ Internalizing $p=0.38$ Hyperactivity $p > 0.05$	Socialization ↔

Table 1 (continued)

Authors	Title	Objective	Participants	Dependent variable	Independent variable	Treatment	Outcome	Effect
Zanobini and Solari (2019)	Effectiveness of the program "Acqua mediatrice di comunicazi-ones" (Water as a mediator of communication) on social skills, autistic behaviors, and aquatic skills in ASD children	To analyze the effectiveness of a swimming program on interpersonal skills, autistic mannerisms, and aquatic abilities in children with ASD	EG ASD: $n=13$ Age: 5.7 ± 1.2 years CG ASD: $n=12$ Age: 5.4 ± 1.5 years	Social responsive-ness	Swimming program	Water-related activities once every two weeks at the swimming pool (12 sessions)	SRS (pre-test and post-test compari-son) $p=0.006$ Social awareness $p > 0.05$ Social cognition $p > 0.05$ Social communica-tion $p > 0.05$ Social motivation $p=0.018$ Autistic manner-isms $p < 0.001$	Socialization ↑ Communication ↑
Zhao and Chen (2018)	The effects of structured physical activity program on social interaction and communication for children with autism	To investigate the effects of struc-tured physical activity pro-grams on social interaction and communication of children with ASD	EG ASD: $n=21$ Age: 6.1 ± 0.9 years CG ASD: $n=20$ Age: 6.1 ± 0.9 years	Social skills	Physical activity program	12-week structured physical activity program (twice a week, 60 min per session, in total 24 sessions)	SSIS (pre-test and post-test compari-son): Social skills standard score $p < 0.005$ Communication $p < 0.005$ Cooperation $p < 0.005$ Assertion $p > 0.05$ Responsibility $p > 0.05$ Empathy $p > 0.05$ Engagement $p > 0.05$ Self-control $p < 0.005$	Socialization ↑

ASD autism spectrum disorder, *ATEC* autism treatment evaluation checklist, *BASC* Behavioral Assessment System for Children, *BL* baseline, *CEPI-PE* Computerized Evaluation Protocol of Interactions in Physical Education, *CG* control group, *COMPASS* Collaborative Model for Promoting Competence and Success, *CPT* combined physical training, *EG* experimental group, *F* female, *F F* test, *FMS* fundamental motor skill, *GARS* Gilliam Autism Rating Scale, *h* hours, *IPA* inclusive physical activities, *M* male, *MBTP* mini-basketball training program, *PF* physical fit-ness, *POPE* Playground Observation of Peer Engagement, *RSB* rating of social behaviors, *SCIP* Social Competence Intervention Program, *SCQ* Social Communication Questionnaire, *SPARK* Sports, Play and Active Recreation for Kids, *SRS* Social Responsiveness Scale, *SRS-2* Social Responsiveness Scale Second Edition, *SSIS* Social Skills Improvement System, *SSRS-PF* Social Skills Rating System-Parent Form, *T* time point, *TD* typical development

↑, increase; ↔, equal

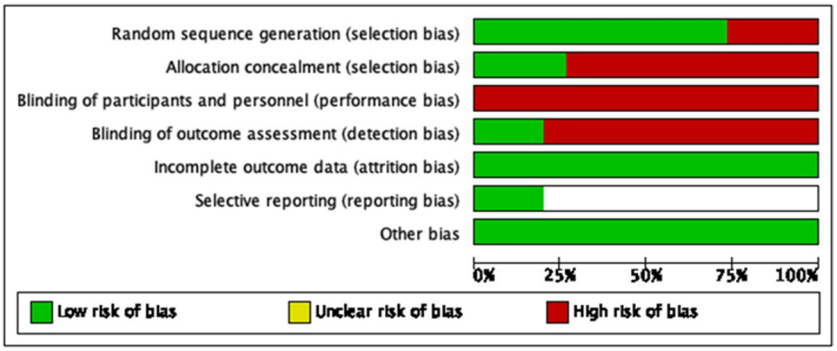

Fig. 2 Risk of bias for the domain of selection bias and detection bias

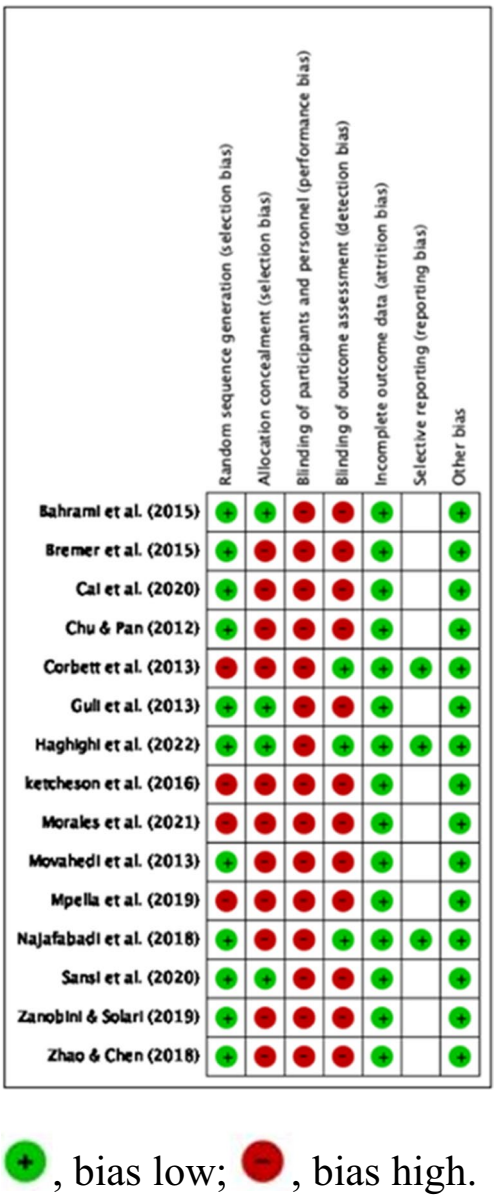

Fig. 3 Studies and domains showing high and low risk of bias

meta-analysis showed inconsistency among the reviewed studies ($I^2 = 0\%$; $p = 0.55$). However, all the studies analyzed stated that PE benefits children and preadolescents with ASD, improving their socialization (Chu & Pan, 2012; Guli et al., 2013; Zhao & Chen, 2018). Only the study of Chu and Pan (2012) (subscale "Social interactions with a trained peer or sibling" in its outcome social interactions with a teacher) showed a neutral effect for this psychosocial variable.

Effect of a PE on Communication (Inverse Scale)

Four reverse-scaled studies were included in the analysis that estimated the effect of PE on communication in children and preadolescents with ASD (Bahrami et al., 2016; Cai et al., 2020; Haghighi et al., 2022; Zanobini & Solari, 2019). Figure 7 shows that PE (physical activity, physical exercise, or sport) generates a small and significant effect on the communication of children with ASD (SMD, −0.44; 95% CI −0.84 to −0.05; $p = 0.03$). The meta-analysis showed inconsistency among the reviewed studies ($I^2 = 0\%$; $p = 0.88$). However, all analyzed studies stated that PE benefits children and preadolescents with ASD, improving communication (Bahrami et al., 2016; Cai et al., 2020; Haghighi et al., 2022; Zanobini & Solari, 2019).

Discussion

This study aimed to determine the effect of PE on socialization and communication skills in children and preadolescents with ASD. Based on the results of the study, it was observed that PE classes have a positive effect on social interaction and communication in children and preadolescents with ASD, strengthening companionship and improving self-esteem as well as motor skills.

Effect of PE on the Communication Skills of Children and Preadolescents with ASD

PE has improved communication skills in children and preadolescents with ASD (Bahrami et al., 2016; Cai et al., 2020; Haghighi et al., 2022; Zanobini & Solari, 2019). Haghighi

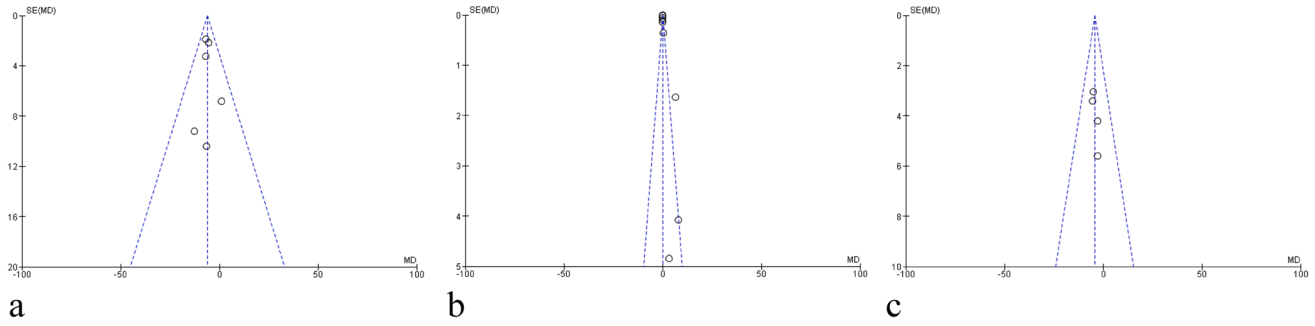

Fig. 4 Primary variables in different scales using Egger's analysis

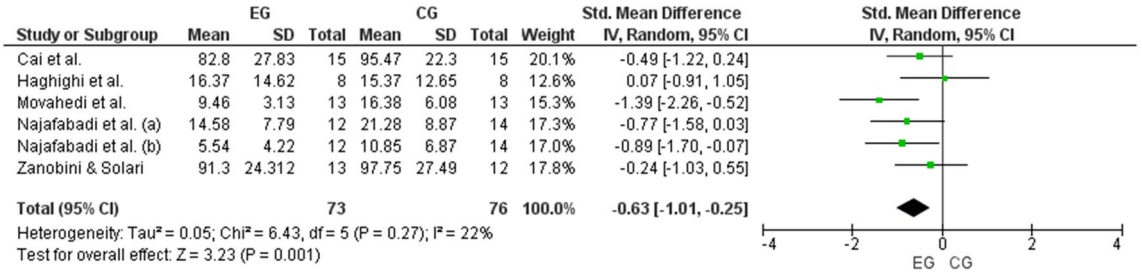

Fig. 5 Six studies with an inverse scale estimated the effect of PE

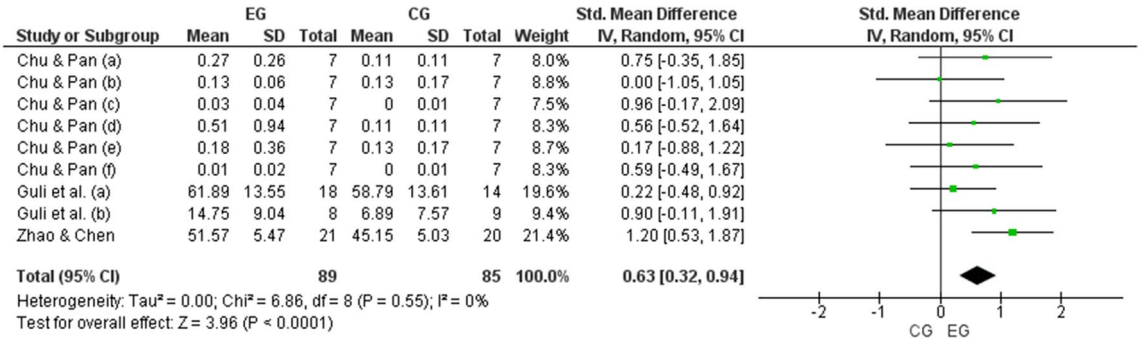

Fig. 6 Nine studies with direct scaling estimated the effect of PE

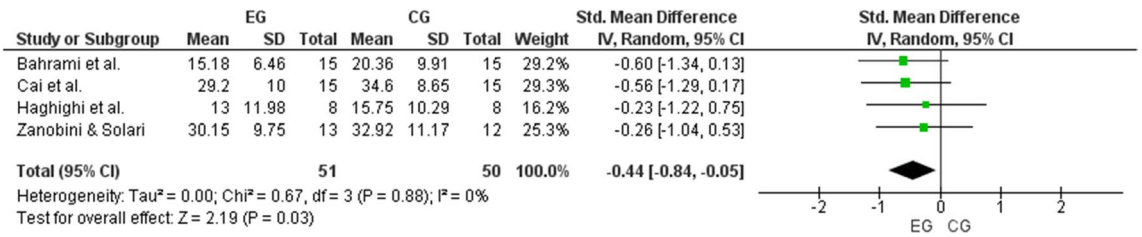

Fig. 7 Four studies with inverse scale estimated the effect of PE

et al. (2022) examined the effects of combined physical training on social skills and physical fitness in children with ASD, who reported a significant effect of physical training on stereotypic behavior and communication ($p < 0.05$). They concluded that combined physical training could improve indicators of social skills in children with ASD (Haghighi

et al., 2022). In this sense, it has been shown that people with ASD need structured activities to adapt to the environment (Coleman-Smith et al., 2020). Therefore, there is a high probability that the combined physical training proposed by Haghighi et al. (2022) has provided an environment conducive to developing social skills and physical fitness in children with ASD. Likewise, it has been shown that PECs help stimulate socialization in children with ASD, among other variables. (Zanobini & Solari, 2019). An example of this was the study developed by Zanobini and Solari (2019), which analyzed the efficacy of a swimming program on interpersonal skills, autistic gestures, and aquatic skills in children with ASD. The researchers concluded that swimming helps improve relational skills in children with ASD by significantly decreasing symptom severity in social communication (Zanobini & Solari, 2019). From a behavioral point of view, the clarity of the instructions that people with ASD should receive is critical to the effectiveness of interventions (Osos et al., 2021). In addition, this increase in communication skills evidenced after the application of physical stimuli (PE) in children with ASD can be explained by their influence on the development of brain neuroplasticity (Cai et al., 2020). In fact, there is evidence that preschool children with ASD have altered functional connectivity between the amygdala and brain regions involved in social communication and language, a clinically relevant situation since weak connectivity is associated with greater severity of autism (Shen et al., 2016). There is also evidence that children with ASD exhibit atypical connectivity in the imitation network, which plays an essential role in the fundamental capacity for social cognition (Fishman et al., 2015). Physical exercise as external stimulation has been shown to increase brain activity in the bilateral parietal cortex, left hippocampus, and bilateral cerebellum, favoring the development of brain plasticity in children (Chen et al., 2016). However, the research in the present systematic review and meta-analysis lacks evidence of improved communication skills in children with ASD through neuroimaging or reports of changes in the neural mechanism following physical stimuli (PE). That is why the modifications and/or adaptations of the neural mechanism, eventually generated after a PE in children and preadolescents with ASD, should be explored and evidenced more specifically (Müller & Fishman, 2018).

Effect of PE Class on Socialization in Children and Preadolescents with ASD

PE is a socialization-enhancing agent in children and preadolescents with ASD (Chu & Pan, 2012; Guli et al., 2013; Movahedi et al., 2013; Najafabadi et al., 2018). In this sense, Chu and Pan (2012) evaluated the effect of peer- and sibling-assisted learning on interaction and aquatic skills in children with ASD. The researchers found that peer-assisted learning is an excellent educational strategy for children with ASD and typically developing children. The method significantly increases social interaction between the two groups (Leaf et al., 2021). Likewise, Movahedi et al. (2013) investigated the effects of long-term training of kata techniques on the social interaction of children with ASD, intervening for 14 weeks with these techniques. At the end of the study, the researchers reported a significant improvement in social dysfunction within the exercised group, concluding that teaching martial arts techniques significantly improves the social interaction of children with ASD (Movahedi et al., 2013). Besides, Najafabadi et al. (2018) evaluated the efficacy of a specific group exercise on motor and behavioral skills in children with ASD, showing significant improvements in social skills in children with ASD. This increase in socialization evidenced after applying physical stimuli (PE) in children with ASD can be explained by neurochemistry (Movahedi et al., 2013). Evidence shows that children with ASD often have alterations in oxytocin secretion and regulation (L. Green et al., 2001; Modahl et al., 1998), as well as abnormal levels of serotonin concentration (Blatt et al., 2010; Chandana et al., 2005). Abnormal levels are attributed to inefficient metabolism in different brain regions in individuals with ASD (Chandana et al., 2005). In fact, there is evidence that both oxytocin and serotonin are directly related to social functioning (Blatt et al., 2010). In this regard, Modahl et al. (1998) associated different levels of oxytocin with social behaviors in children with ASD and typically developing children. In this regard, the researchers observed that typically developing children had elevated oxytocin levels and higher scores on social measures. In contrast, children with ASD had reduced plasma levels and lower social measures (Modahl et al., 1998). Evidence has shown that improved physical fitness is associated with improved social-cognitive abilities (Ludyga et al., 2020). In this sense, there is evidence that physical fitness is directly associated with the autonomic balance, function, and structure of brain social networks (Ludyga et al., 2022). Although data suggest that alterations in oxytocin and serotonin may influence ASD, it is difficult to determine from plasma concentrations the functioning of these neurotransmitters at the central level (Modahl et al., 1998). This background warrants a more specific investigation of the functioning of oxytocin and serotonin in the central nervous system and the effect of CEP on these neurotransmitters.

Limitations

Although in the present systematic review and meta-analysis, it was possible to estimate the ES of PE on communication skills and socialization in children and preadolescents with ASD, these interventions lack neuroimaging or reports showing changes in the neural mechanism following

physical stimuli. Likewise, oxytocin and serotonin were shown to condition central nervous system functioning and influence communication skills and socialization in children and preadolescents with ASD. However, none of the research selected for the present review evidenced the effect of CEP on these neurotransmitters. Finally, due to the nature of the sports used in the study selected for the current meta-analysis, it was not possible to establish the ES by sport modality (individual or group sports) in CEP on communication and socialization skills in children and preadolescents with ASD. Consequently, it would be interesting to study which sports modality generates more communication skills or socialization changes in this population.

Conclusion

In its broad spectrum, PE effectively increases socialization and communication skills in children and preadolescents with ASD. Finally, considering the impact of physical activity and exercise on socialization and communication skills, it is important to consider including children and preadolescents with ASD in PE throughout the school stage.

Perspective

From a physiological point of view, the neurotransmitters oxytocin and serotonin (which increase with physical activity and exercise) are directly related to social functioning, significantly influencing the autonomic balance, function, and structure of social brain networks. In parallel, physical exercise increases brain activity in the bilateral parietal cortex, left hippocampus, and bilateral cerebellum, favoring the development of brain plasticity in children. Therefore, future studies should include neurotransmitter monitoring and neural network mapping to determine the effect of PE on socialization and communication in children and preadolescents with ASD.

Practical applications

Communities that work with children and preadolescents with ASD, especially educational communities, should include professionals trained in physical education within the multidisciplinary teams. Thus, activities such as aquatic activities, theatrical play sessions, instruction of karate techniques, judo, ball games, rhythmic movements, and resistance training, among others described in this study, could be applied in different educational contexts to achieve similar results and, consequently, improve socialization skills such as communication. On the other hand, it is suggested that the activities selected for developing socialization and/or communication skills have a playful and inclusive character, respecting the processes and responses of each participating child and preadolescent.

Author Contribution All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Álvaro Huerta Ojeda, Guillermo Barahona-Fuentes, Franchesca Villagra Órdenes, and Maríajosé Mena Tapia. Álvaro Huerta Ojeda wrote the first draft of the manuscript, and all authors commented on previous versions. All authors read and approved the final manuscript.

Declarations

Conflict of Interest The authors declare no competing interests.

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