Rehabilitation & Recreation
Volume 20 No.3(2026)

https://doi.org/10.67034/2786-8354.2026.20.3.04

EXERCISE MODALITIES FOR IMPROVING MOTOR AND BEHAVIOURAL OUTCOMES IN AUTISM SPECTRUM DISORDER: A COMPARATIVE NARRATIVE REVIEW

МОДАЛЬНОСТІ ФІЗИЧНИХ ВПРАВ ДЛЯ ПОКРАЩЕННЯ РУХОВИХ І ПОВЕДІНКОВИХ РЕЗУЛЬТАТІВ ПРИ РОЗЛАДАХ АУТИСТИЧНОГО СПЕКТРА: ПОРІВНЯЛЬНИЙ НАРАТИВНИЙ ОГЛЯД

Priyadharsni P.[1], Akilandeswari S.[2], Vanithamani P.[3], Sakthivel S.[4]

[1,2,3]Department of Physical Education, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu, India

[4]Faculty of General & Adapted Physical Education and Yoga, Ramakrishna Mission Vivekananda Educational and Research Institute, Coimbatore, Tamil Nadu, India

ORCID: 0000-0003-3077-6582
ORCID: 0000-0001-6831-1217
ORCID: 0000-0002-8768-7671
ORCID: 0000-0002-6976-9630

Abstracts

Objective – to compare the effects of different exercise modalities on motor performance and behavioural outcomes in individuals with autism spectrum disorder (ASD) and to inform individualised exercise prescription.

Materials and Methods. A narrative review was conducted following the Scale for the Assessment of Narrative Review Articles (SANRA). Electronic databases were searched for English-language studies published between 2008 and 2025. A total of 46 eligible sources, comprising primary empirical studies and secondary evidence including systematic reviews and meta-analyses, were identified and included in the review. The primary empirical evidence evaluated aerobic exercise, aquatic exercise, yoga, martial arts, resistance training, and exergaming in individuals with ASD.

Results. The review included 46 eligible sources, including primary empirical studies, systematic reviews and meta-analyses, which provided context and interpretation of the findings. The length of the intervention typically was 6-24 weeks, and the number of exercise sessions was 2-5 per week. The exercise modalities most commonly studied were aerobic exercise, aquatic exercise, yoga, martial arts, exergaming, and resistance training. The evidence from the included studies was generally positive regarding the benefits of structured exercise for motor performance, physical fitness, executive functioning, behavioural regulation, and social participation, with included evidence varying in strength and consistency across the modalities and outcome domains. The scope of the benefits reported from aquatic exercise was wide, ranging from motor to behavioural, social and physical, but this may be due in part to variations in intervention characteristics and outcome selection. The main areas of development for yoga were self-regulation and sensory processing, and for martial arts, motor competence and social interaction. Evidence was favourable, and although fewer studies were available, the evidence for resistance training and exergaming was positive.

Conclusions. Structured exercise is an effective complementary intervention for individuals with ASD, with different exercise modalities demonstrating distinct therapeutic strengths. Exercise prescription should therefore be individualised according to functional goals, clinical characteristics, and personal preferences. Future comparative trials using standardised outcome measures and longer follow-up periods are needed to strengthen the evidence base for precision exercise prescription.

Keywords: Autism Spectrum Disorder, Adapted Physical Activity, Aerobic Exercise, Aquatic Exercise, Behavioural Regulation, Exercise Intervention, Exergaming, Motor Skills, Martial Arts and Yoga.

Мета. Порівняти вплив різних видів фізичних вправ на рухові показники та поведінкові результати в осіб із розладом аутистичного спектра (РАС), а також обґрунтувати індивідуалізований підхід до призначення фізичних вправ.

Received: 25 July 2026. Accepted: 30 October 2026. Available online: 30 October 2026

© 2026. Priyadharsni P., Akilandeswari S., Vanithamani P., Sakthivel S.
Rehabilitation and Recreation. ISSN 2786-8354 (Online) | ISSN 2786-8346 (Print)
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

Матеріали та методи. Було проведено наративний огляд відповідно до Шкали оцінювання якості наративних оглядових статей (Scale for the Assessment of Narrative Review Articles, SANRA). Електронний пошук у базах даних проводився серед англомовних досліджень, опублікованих у період з 2008 по 2025 рік. Загалом було виявлено та включено до огляду 46 джерел, що охоплювали первинні емпіричні дослідження та вторинні джерела доказів, зокрема систематичні огляди й метааналізи. Первинні емпіричні дослідження оцінювали вплив аеробних, водних, йоги, бойових мистецтв, силових тренувань та ексергеймінгу (exergaming) на осіб із РАС.

Результати. До огляду було включено загалом 46 відповідних джерел, серед яких первинні емпіричні дослідження, систематичні огляди та метааналізи, що використовувалися для контекстуалізації та інтерпретації отриманих результатів. Тривалість втручань переважно становила від 6 до 24 тижнів, а частота занять – 2-5 разів на тиждень. Найчастіше досліджувалися аеробні та водні вправи, за якими йшли йога, бойові мистецтва, ексергеймінг і силові тренування. У більшості включених досліджень структуровані фізичні вправи загалом асоціювалися з покращенням рухових показників, фізичної підготовленості, виконавчих функцій, поведінкової регуляції та соціальної участі, хоча сила та послідовність доказів відрізнялися залежно від виду вправ і результату, що досліджувався. Водні вправи продемонстрували широкий спектр повідомлених переваг у руховій, поведінковій, соціальній та фізичній сферах, хоча широта зазначених ефектів частково може пояснюватися відмінностями в характеристиках втручань і виборі показників результатів. Йога переважно сприяла покращенню саморегуляції та сенсорної обробки, тоді як бойові мистецтва – руховій компетентності й соціальній взаємодії. Докази щодо силових тренувань та ексергеймінгу були позитивними, але порівняно обмеженими через меншу кількість доступних досліджень.

Висновки. Структуровані фізичні вправи є ефективним додатковим втручанням для осіб із РАС, причому різні види фізичних вправ демонструють специфічні терапевтичні переваги. Тому призначення фізичних вправ має бути індивідуалізованим з урахуванням функціональних цілей, клінічних характеристик і особистих уподобань. Для посилення доказової бази щодо персоналізованого призначення фізичних вправ необхідні майбутні порівняльні дослідження із застосуванням стандартизованих показників результату та тривалішими періодами спостереження.

Ключові слова: розлад аутистичного спектра, адаптована фізична активність, аеробні вправи, водні вправи, поведінкова регуляція, фізичні вправи як втручання, ексергеймінг, рухові навички, бойові мистецтва та йога.

1. Introduction

Autism Spectrum Disorder (ASD) is a condition of the brain that is characterised by persistent social communication and social interaction deficits and restricted and repetitive patterns of behaviour, interests, or activities [2]. In addition to these basic features, individuals with ASD often have motor impairments, sensory processing dysfunction, behavioural issues, and reduced involvement in physical activity, all of which can have a negative impact on health, independence and quality of life [5; 15; 45].

Common additional features of ASD include motor problems and delays in balance, coordination, motor planning, and basic movement skills, which can negatively affect functional independence and participation in daily activities [15; 45]. They are associated with lower levels of physical activity and reduced physical fitness compared with typically developing peers [17; 44]. In addition, early acquisition and maintenance of fundamental movement skills is emerging as another potential factor for long-term physical activity engagement and health-related fitness for children with ASD [46]. Interventions addressing motor, behavioural, cognitive and physical health outcomes are therefore gaining traction, as they can enhance participation, social engagement and health throughout life.

There is increasing evidence that structured physical activity is a potential non-pharmacological intervention that can have several benefits for individuals with ASD. Exercise has been linked to enhanced motor competence, behavioural regulation, cognitive functioning, social participation and physical health, and is thus becoming an increasingly vital part of multidisciplinary care [7; 9; 18; 42; 43]. This has led to an emerging view that physical activity should be considered a supportive, complementary intervention that can improve functional outcomes and general health alongside the educational, behavioural, and clinical supports employed [11; 41].

Several previous systematic reviews and meta-analyses have shown the overall benefits of exercise for individuals with ASD, but they have tended to focus on a single exercise modality, specific outcome domains, or select age groups [7; 9; 11; 18; 40]. As a result, there is a lack of guidance on the comparative effectiveness, clinical application, and selection of exercises for various development goals and functional needs.

2. Purpose of the study

This is a structured narrative review that synthesises and critically compares current evidence regarding the effects of various exercise modalities on motor, behavioural, cognitive, social and physical outcomes in individuals with ASD. The review combines results from aerobic exercise, aquatic exercise, martial arts, yoga, resistance training, exergaming, and other structured physical activity interventions to determine the relative strengths, mechanisms, and clinical applications of these interventions, as well as priorities for future research. The objectives of this review are to summarise the available evidence, highlight knowledge gaps and provide practical recommendations for prescribing exercise for individuals.

3. Materials and Methods

Review Design. The review aimed to assess the effects of exercise and structured physical activity interventions in individuals with ASD. This study was undertaken as a structured narrative review of exercise interventions and structured physical activity programmes. Guidance for the review was provided by the Scale for the Assessment of Narrative Review Articles (SANRA) to ensure methodological transparency, adequate justification of literature search, clear presentation of the evidence and critical appraisal [3]. Additionally, a pre-established literature search and study selection process was conducted, comprising explicit eligibility criteria, sequential screening, methodological quality appraisal, and structured narrative synthesis. The review was designed to synthesise findings from exercise modalities and across outcome domains, considering participant, intervention characteristics, and the methodological quality and consistency of the findings.

Literature Search Strategy and Study Selection. The literature review was conducted in PubMed, Scopus, Web of Science, and Google Scholar using the following keywords to identify relevant studies published from 2008 to 2025. The reference lists of pertinent review articles and primary empirical studies were also hand-searched for other eligible studies. The search strategy was the following: ("Autism Spectrum Disorder" OR autism OR ASD) AND ("exercise" OR "physical activity" OR "aerobic exercise" OR swimming OR "aquatic therapy" OR yoga OR "martial arts" OR "resistance training" OR exergaming OR sports). Each database's indexing needs were met using adapted search terms. There were 289 records found through database searches and additional hand searching. 71 duplicate records were eliminated, leaving 218 records for title/abstract screening. After screening the titles and abstracts, 144 records were excluded because they were out of scope for the review or did not meet the predefined eligibility criteria. The full text of the remaining 74 articles was evaluated for eligibility. Of these, 28 articles were excluded for the following reasons: inappropriate population (n = 13), insufficient relevance to exercise outcomes in ASD (n = 6), and inappropriate intervention (n = 9). Lastly, 46 studies were eligible and included in the narrative synthesis, according to the pre-established criteria.

The 46 eligible sources comprised primary empirical studies and secondary evidence, including systematic reviews and meta-analyses. Primary empirical studies formed the principal evidence base for the narrative synthesis, whereas systematic reviews and meta-analyses were used as background sources to contextualise and interpret the findings. Secondary sources were not treated as primary empirical studies in the methodological quality assessment or in assigning the qualitative ratings presented in Table 2.

Eligibility Criteria. Studies that met the following criteria were included: enrolled subjects with a reported diagnosis of ASD, and examined an exercise, structured physical activity or exercise-based intervention. The studies had to assess at least one of the following: motor performance, behavioural functioning, cognition, sensory functioning, social participation, physical fitness, and/or quality-of-life outcomes associated with the exercise or structured physical activity intervention, and be reported in English. Primary empirical study designs (randomised controlled

trials (RCTs), quasi-experimental studies, pilot studies, cohort studies) were eligible.

Studies were ineligible if they included an inappropriate population, lacked a strong connection to ASD and exercise-related outcomes, used an intervention unrelated to exercise or structured physical activity, or did not meet other pre-specified criteria. In particular, studies that did not include participants with an ASD diagnosis, studies that examined only the effects of drug interventions, and studies that reported outcomes that were not associated with exercise participation were excluded.

Systematic reviews and meta-analyses were used as background resources to identify pertinent primary empirical studies and to aid interpretation of the findings, and were not presented as part of the narrative synthesis of the primary empirical studies.

In the screening process, duplicate removal and title and abstract screening were conducted first, followed by full-text evaluation. Two independent reviewers screened titles and abstracts, then conducted full-text eligibility assessments using the predefined eligibility criteria. Disagreements were addressed and resolved through discussion and consensus, and with reference to a third reviewer where needed. Records were rejected at the title and abstract levels if they were clearly unrelated to ASD exercise, physical activity, or the predetermined outcome domains. The entire texts were then evaluated according to the predetermined criteria of population, intervention, outcome, language and study design. The methodological quality assessment was conducted independently, and consensus was reached regarding any discrepancies. The studies were eligible for inclusion in the final synthesis if they met the following criteria: exercise modality, participant characteristics, type and duration of intervention, outcome domain, and study design.

Methodological Quality Assessment of Included Primary Empirical Studies. Methodological quality was assessed using design-appropriate appraisal instruments to account for the heterogeneity of the primary study designs included in the review. RCTs were evaluated using the Physiotherapy Evidence Database Scale (PEDro), and quantitative intervention and observational studies were evaluated using the Downs and Black checklist. The CASP Qualitative Studies Checklist was used to appraise qualitative studies. The topic of appraisal instruments was closely linked to the study design to ensure a uniform evaluation of the methodological strengths and weaknesses of the included primary empirical evidence.

RCTs were used to evaluate methodological quality of the research using the PEDro Scale. There are 11 items (item 1 is not included in the total score because it refers to eligibility criteria). A score of ≥9 was considered "excellent", 6–8 was "good", 4–5 was "fair", and ≤3 was "poor". Both quantitative intervention and observational studies were carried out using the Downs and Black checklist. It includes 27 items for reporting, external validity, internal validity/bias, and statistical power. The scores were judged as good (20+), fair (15-19), limited (10-14) or poor (<10) for the present review. For qualitative studies, the CASP Qualitative Studies Checklist was applied, and no formal quality category was assigned, as CASP does not have a validated quantitative score threshold for such studies.

The consistency and strength of the findings were assessed using a methodological quality appraisal, which also provided contextual information. The studies were not excluded because of their appraisal results; they were excluded only if they had methodological shortcomings. The results of lower-quality studies were interpreted with increased caution. The assessment did not include formal grading of the certainty of evidence or risk of bias across all study designs; it identified potential methodological limitations and biases that could affect the interpretation of the findings. Results of the appraisal are presented in Supplementary Table S1, including study design, appraisal instrument, total score, and quality interpretation.

Data Synthesis. The studies reviewed were categorised based on the following: exercise modality, participant characteristics, intervention design, intervention duration, outcome domain, and main findings. The evidence was grouped into the following general categories of exercise interventions: aerobic exercise, aquatic exercise, yoga and mind-body interventions, martial arts, resistance training, exergaming, and sport-based programmes. The synthesis aimed to (1) compare the different types of intervention; (2) look for patterns and inconsistencies in the outcomes reported; (3) reflect on methodological limitations;

and (4) note practical implications and gaps in the evidence available.

To facilitate comparison between exercise modalities, the evidence in Table 2 was qualitatively categorised according to the number of primary empirical studies supporting each finding, the consistency of the findings and the methodological quality of the supporting evidence. When the evidence was limited, qualitative support was limited, when the evidence was based on a single primary empirical study, or when findings were inconsistent, a rating of ✓ (limited qualitative support) was applied. A rating of ✓✓ (moderate level of qualitative support) was given, where there were 2-3 primary empirical studies with moderate consistency of findings, and mostly low or low-quality methods. A rating of ✓✓✓ (relatively stronger and more consistent qualitative support) was given if evidence was obtained from ≥4 primary empirical studies, showing generally consistent beneficial findings, and from at least 2 fair or better rated studies with methodological support. A rating of – was given when no good primary empirical evidence was found for the corresponding outcome. If there was an overlap between rating criteria, the lower rating was used. When assigning the qualitative ratings, systematic reviews and meta-analyses were not included as separate primary empirical studies, but were included for contextual interpretation. The ratings were not intended to be a formal assessment of the certainty of evidence, the effect size, statistical significance, or methodological quality of the available evidence and were only intended to describe the quality and methodological quantity of the evidence.

Overview of the Reviewed Literature. The literature reviewed included aquatic exercise, aerobic exercise, yoga, martial arts, resistance training, exergaming and sport-based programmes. Of these, aquatic exercise, yoga, and sport-based interventions were the most often studied, with aquatic exercise and yoga as the most common [7; 9; 11; 18; 43].

Most studies focused on children and adolescents, and those that examined adults or individuals with severe ASD had relatively small sample sizes [7; 9; 11; 18; 36]. The length of interventions ranged from one session to those lasting over three months, with most delivered two to three times a week for 8 to 12 weeks [8; 10; 13; 20; 29].

The methodologies used, interventions applied, programme lengths, and outcome measures reported in the literature show considerable variation [7; 9; 11; 18; 34]. This overview does not assess the relative effectiveness of the different exercise modalities; rather, it sets the context for the comparative synthesis in the next section.

These studies were purposively selected to provide representative coverage of the evidence base for the major exercise modalities included in the review: aerobic, aquatic, martial arts, yoga, resistance training and exergaming. They were selected based on their representation of different exercise modalities, participant features, intervention duration and design, and primary outcome domains, not on the magnitude, statistical significance or direction of the reported findings. The studies selected were not, however, chosen for other reasons, such as being more effective or higher quality, or to draw the review's final conclusions, but rather are representative examples of the evidence synthesised in the review.

Methodological Quality of Included Primary Empirical Studies. There was variation in the methodological quality of the primary empirical studies included in the methodological quality assessment. Studies assessed using the PEDro scale showed moderate to good methodological quality, whereas those assessed using the Downs and Black checklist showed a wider range of methodological quality. The qualitative study was appraised using the CASP Qualitative Studies Checklist; because CASP does not prescribe a validated numerical scoring threshold, the appraisal was interpreted descriptively rather than assigned to a formal quality category. In general, the evidence base was seen to consist of studies of different methodological quality. These data were considered in interpreting comparative evidence across the different exercise modalities. Supplementary Table S1 provides detailed information on the study level, such as the study design, appraisal instrument, total score and quality interpretation.

Table 1

Key Representative Intervention Studies Included in the Narrative Review

Exercise Modality	Sample Size (n)	Participants	Duration	Primary Outcomes
Physical Activity	200	Mixed-Age Individuals from 4–18 with ASD	Single 60-minute treadmill walking session (acute/ immediate exercise intervention)	Autonomic Nervous System Responses [1]
Fundamental Motor Skills Training	11	4 years Preschool Children with ASD	12 weeks, 2 sessions/week, 60 minutes/session	Motor Performance [5]
Acute Aerobic Exercise	12	8–12 years male children with ASD	Single acute exercise session -20 minutes of moderate-intensity exercise	Executive Functioning, Inhibitory Control [8]
Mini-Basketball Training	59 EG=30 CG=29	3-6 years preschool children with ASD	12 weeks, 5 sessions/week, 40 minutes/session	Physical Fitness, Social Communication [10]
Aquatic Therapy	30 EG=15 CG=15	6–10 years Children with ASD	8 weeks, 3 sessions/week, 60 minutes/session	Motor Performance, Executive Functioning [13]
Martial Arts	42 EG=21 CG=21	5–8 years Children with ASD	12 weeks 3 sessions/week, 60 minutes/session	Motor Performance, Behavioural Outcomes [16]
Yoga	60 EG=30 CG=30	5–8 years Children with ASD	12 weeks, 3 sessions/week, 60 minutes/session	Motor Coordination, Behavioural Regulation [20]
Yoga	24	5–13 years Children with ASD	8 weeks, 2 sessions/week, 60 minutes/session	Motor Performance, Imitation Skills [21]
Taekwondo Training	10	6–12 years Children with ASD	16 weeks, 2 sessions/week, 60 minutes/session	Physical Ability, Social Communication [27]
Aquatic Exercise	16	6–9 years Children with ASD	10 weeks, 2 sessions/week, 90 minutes/session	Aquatic Skills, Social Communication [29]
Yoga	30	Children with ASD 6–12 years	8 weeks, 3 sessions/week, 60 minutes/session	Balance, Physical Fitness [33]
Exergaming	24	Mixed-Age Individuals with ASD 7–14 years	12 weeks, 3 sessions/week, 40 minutes/session	Aerobic Fitness, Muscular Strength [35]

Note: *Table 1 presents 12 representative intervention studies from the 46 studies included in the narrative synthesis.*

Comparative Effects of Exercise Modalities in ASD. There is no consistent evidence from the comparison to suggest superiority of any exercise modality in all outcome domains. Instead, patterns of findings vary depending on the intended outcome, the characteristics of the participants, the dosage of the intervention, the type of programme and the methodological design. Aerobic exercise also seems to have a fairly uniform effect on cardiorespiratory fitness and selected cognitive outcomes in the literature, whereas aquatic exercise has a broader effect across the motor, behavioural, social and physical domains. Yoga seems to be more strongly associated with self-regulation and sensory outcomes, whereas martial arts and structured sports are more strongly associated with physical activity, motor learning, and social interaction [1; 8; 11; 13; 18; 20; 27; 29; 33; 40]. These patterns should not, however, be taken to imply that one modality is superior, as the modalities have not generally been compared

under equivalent intervention and assessment conditions.

The evidence is also diverse regarding participant age, sample size, exercise intervention duration, intensity, frequency, outcome measures, and study design. These differences are demonstrated by the studies in Table 1, which are representative of both acute exercise exposure and 8–16 week programmes across different age groups and outcome domains. Thus, reported effects may be influenced by differences in study characteristics, which may account for some of the variation in effects by exercise modality.

Aquatic Exercise. One of the broader trends in reported benefits was aquatic exercise, which was reported to improve motor coordination, balance, physical fitness, social interaction, behavioural functioning and selected strength-related outcomes [13; 24; 28; 29]. The range of reported benefits must be taken with some caution, however, due to the variability of the studies supporting the programmes in terms of programme structure, duration, frequency, participant characteristics and outcome measures. This apparent multidimensional benefit might therefore be related to the characteristics of the aquatic environment as well as to variability in intervention design and outcome selection.

In the representative study, aquatic programmes lasted about 8-10 weeks, but session intensity and duration varied from one programme to another. These differences can make cross-study comparisons difficult and harder to gauge whether similar results would be seen with different doses of the intervention or for different functional or support needs. Furthermore, the number and types of outcome measures used varied across studies, which may also account for the wide effect profile of water exercise.

The aquatic setting can simultaneously offer opportunities for movement practice, sensory stimulation, balance and social interaction, which may lead to positive outcomes across multiple domains. However, these mechanisms cannot be considered as proof of modality-specific superiority. Overall, the evidence indicates that aquatic exercise has a wide range of therapeutic applications, but at present, there is no evidence that it is superior to other modes of exercise.

Martial Arts and Structured Sport Programmes. The martial arts and structured sport-based interventions involve a combination of physical activity, adherence to structured rules, sequencing, goal-oriented practice and social interaction. Studies on judo, taekwondo, mini-basketball, tennis and other structured activities indicated increases in motor competence, social-communication skills, behavioural control, and physical fitness [10; 16; 27; 30; 39]. The results must be interpreted with caution, as a number of differences exist in the task demands, social structure, exercise intensity, skill demands, and opportunities for interaction between the interventions grouped in this category.

The wide range of outcomes reported may be related to the mix of motor and social demands, but this is a hypothesis and not directly substantiated by comparing outcomes between the two groups. However, the available evidence is insufficient to make the different activities comparable interventions. The variability in findings could be due to differences in programme structure, participant characteristics, intervention duration, and outcome measures. This means that progress outcomes for individual programmes of a structured sport or martial arts activity cannot be extrapolated to the entire sport or martial arts category.

The overall evidence indicates potential benefits for motor function and selected behavioural and social outcomes with structured and socially interactive exercise, but does not suggest that martial arts or sport-based programmes are better than aerobic, aquatic or mind–body programmes. Further comparative research will be conducted using standardised outcome measures and intervention protocols to identify if there are modality-specific benefits of certain activities.

Aerobic Exercise. More comprehensively studied exercise modalities included aerobic exercise, which was linked to enhancements in cardiorespiratory fitness, executive functioning, attention, inhibitory control, behavioural regulation and, in some instances, stereotypical behaviours [1; 8; 11; 14; 18; 47]. These results indicate fairly similar advantages in physiological fitness and some cognitive outcomes, but not as consistent in social participation and sensorimotor outcomes. This variation suggests that the benefits of aerobic exercise might be specific to a functional domain and not generalise to all domains of functioning.

The magnitude of the aerobic evidence should also be compared with the substantial variation in

intervention exposure and study designs. Comparisons are not easily made, since acute exercise sessions and repeated exercise programmes have been reported in the literature. For instance, the representative studies are based on a single acute aerobic exercise session, and on structured programmes that last several weeks. Changes observed after an acute session cannot be assumed to be the same as those observed on repeated exposure. There are also a variety of factors, such as participants, interventions, intensity, and outcome measures, that restrict the ability to compare findings across studies. The evidence suggests that aerobic exercise is more relevant for cardiorespiratory fitness and selected executive functions, but there is no evidence for general superiority over socially interactive or multimodal exercises.

Yoga and Mind-Body Interventions. Other mind-body interventions, such as yoga, were reported to have effects that differed from those of the others, including improvements in self-regulation, emotional regulation, sensory processing, balance, motor coordination, and behaviour [20; 21; 33; 38]. The evidence must be viewed with caution, though, as there are differences in elements, intensity, duration, and delivery methods in the different yoga interventions. These differences may make it hard to pinpoint which aspect of yoga (controlled movement, breathing, thought, and/or body awareness) is responsible for the benefits observed.

The reported improvements in the behavioural and sensory domains provide a possible justification for yoga as a therapeutic approach targeting self-regulation and sensorimotor processing. However, the evidence is insufficient to determine which specific factors are responsible for these effects, and the different outcome measures make it difficult to directly compare these across the studies. Other than this, any resulting impacts on physical fitness and strength seem to be less strong than those seen with aerobic or resistance training [20; 21; 33; 38].

Yoga could be especially applicable when self-regulation, sensory processing, emotional control, and selected motor outcomes are therapeutic goals. The conclusions drawn, however, should be considered domain-specific potential benefits and additional well-designed studies with a standardised protocol for intervention are required to identify which components and outcomes are likely to be most consistently affected.

Resistance Training and Strength-Based Interventions. Evidence for resistance training was more limited; however, several studies reported improvements in muscle strength, physical function, postural control, and functional capacity [4; 32; 48]. Central stability exercises have also been linked to enhancement of sensorimotor development and postural control in children with high-functioning ASD [4]. But the few studies conducted and the focus on the physical and functional outcomes reduce the extent to which general conclusions can be drawn. The evidence for resistance training is therefore more limited in scope than that for modalities like aerobic or aquatic exercise. This could be due to the physiological effects of resistance training and simply the smaller body of evidence. Further, variations in intervention methods, participant characteristics and outcome measures make direct comparisons between studies difficult. Where there is no consistent evidence for behavioural or social outcomes, this does not imply that no effect occurs; it simply means that there is currently no evidence to determine whether the effect will be consistent.

In summary, resistance training seems most relevant as an adjunctive modality when strength training, postural control, physical performance or functional capacity is a primary objective. Whether it can contribute to broader outcome measures of behaviour, cognition, sensory, and social remains unclear, and additional controlled studies are needed to investigate this, with well-defined resistance training protocols and standardised outcome measures.

Exergaming and Technology-Assisted Exercise. Exergaming is a new modality, and some studies have shown positive effects on motor competence, executive functioning, physical fitness, and exercise engagement [12; 23; 35]. The interactivity can also serve as a motivational element, especially for those who are not inclined to exercise in traditional ways. The evidence base is, however, limited in scope, and some studies use different designs, making it difficult to draw firm conclusions across outcome domains. There are wide variations in the platform, game content, intensity, duration, participant characteristics, and outcome measurement of exergaming interventions. These differences make it difficult to

compare studies and to conclude whether the observed improvements are due to the exergaming itself, to increased engagement or to the nature of specific programmes. Moreover, evidence of improved engagement does not necessarily imply lasting adherence and/or long-term functional benefit.

Current evidence indicates that exergaming-based approaches have the potential to improve engagement, motor learning, and some cognitive outcomes, and add to, rather than displace, existing exercise modalities. More controlled, comparable investigations with standardised intervention protocols and longer follow-up periods are necessary to elucidate whether greater engagement equates with continued participation and clinically relevant functional outcomes.

If more than one criterion was applicable, the lowest rating was given. The narrative synthesis was contextualised by systematic reviews and meta-analyses, but not included as a primary empirical study in the rating. These ratings provide a general sense of the amount, uniformity and methodological quality of the evidence and are not to be interpreted as evidence ratings, effect sizes, statistical significance, or certainty-of-evidence ratings.

4. Discussion

The comparative results indicate that the type of exercise alone is unlikely to account for the observed differences. Instead, the observed patterns are likely due to interactions between the physiological, motor-learning, sensory, cognitive and psychosocial demands of each intervention and the characteristics of the participants receiving it [8; 19; 20; 29; 31; 33; 40]. Importantly, no single modality can be considered consistently better. On the other hand, the relative value of an intervention seems to be related to the targeted outcome and the extent to which its characteristics align with the person's functional needs. A crucial point is that the evidence exhibits a high degree of heterogeneity.

There was variability in age range, baseline functional ability, intensity and duration of intervention, frequency, setting, outcome measures, and methodological design of the studies. This variation is illustrated by the studies listed in Table 1, which range from single-session acute exercise to programmes lasting weeks. The differences preclude direct comparison between modalities and make it difficult to know whether the seemingly different outcomes reflect true effects of the modality or differences in populations and in the delivery of the intervention.

There is also variation in the quality of primary evidence, as suggested by the methodological quality assessment. So, results from studies with varying methodological quality cannot be given equal weight. The qualitative ratings in Table 2 do not represent evidence grades or comparisons of estimated effectiveness levels; rather, they reflect the extent and consistency of the findings.

Table 2

Comparative Effects of Exercise Modalities Across Outcome Domains

Exercise Modality	Motor	Behavioural	Cognitive	Social	Fitness
Aquatic Exercise	✓✓✓	✓✓	✓✓	✓✓	✓
Martial Arts	✓✓	✓✓	✓	✓✓	✓
Aerobic Exercise	✓✓	✓✓	✓✓✓	✓	✓✓✓
Yoga	✓✓✓	✓✓	✓✓	✓	✓
Resistance Training	✓	✓	✓	–	✓✓
Exergaming	✓✓	✓	✓✓	✓	✓

Note: *Qualitative ratings were assigned using predefined criteria based on the number of supporting primary empirical studies, consistency of findings, and methodological quality. ✓ (limited qualitative support) was assigned when evidence was based on one primary empirical study, when findings were inconsistent, or when the supporting evidence was predominantly of low or limited methodological quality. ✓✓ (moderate qualitative support) was assigned when evidence was based on 2–3 primary empirical studies with generally consistent findings and without predominantly low or limited methodological quality. ✓✓✓ (relatively stronger and more consistent qualitative support) was assigned when evidence was based on ≥4 primary empirical studies with generally consistent beneficial findings, and at least two studies rated fair or better for methodological quality (insufficient evidence) indicated that no satisfactory primary empirical evidence was identified for the corresponding outcome.*

Age-Related Differences in Exercise Responsiveness. The majority of the studies reviewed included children and adolescents, and there was a limited number of studies on adults [7; 9; 11; 18; 36]. Research involving younger children found gains in adaptive behaviour, balance, coordination, and fundamental motor skills [8; 21], and research with young and young-adult participants found gains in physical fitness, self-regulation, mental health and community involvement [36].

The results of this study suggest developmental differences in exercise responsiveness, but this is speculative. Developmental comparisons are difficult because adults are underrepresented and intervention types and outcome measures vary by age group. This may, therefore, in part be due to the distribution of available evidence, and not necessarily to a biological effect of younger age. This distinction is significant because the evidence reviewed cannot be used to determine if the same interventions would have a similar impact throughout the lifespan.

Influence of Symptom Severity and Functional Characteristics. Participants' characteristics also seem to affect intervention response. The findings indicate that there are greater improvements in behavioural, cognitive and social outcomes for individuals with mild-to-moderate ASD than for people with higher needs [13; 27]. For those with motor coordination issues, motor learning activities such as martial arts or aquatic exercise might be more relevant, and for those with sensory processing and emotional regulation issues, yoga and mind–body activities may be more relevant [20; 33].

The apparent differences should be taken with a grain of salt, though, as the available evidence is limited and does not capture the whole spectrum of ASD. Others were restricted to the set of participants with a specific level of intellectual disability, behavioural disorders, or complex support needs, limiting the generalisability [13; 27]. Thus, the observed decrease in benefit among those needing the most support does not necessarily mean they are less responsive to exercise; it may be due to differences in access to exercise, intervention adaptation, sample selection, or outcome measurement.

Population Specific Considerations and Exercise Selection. The comparative evidence, along with the functional characteristics and therapeutic goals of the individual, as well as the clinical context, supports the choice of exercise based on the individual's functional characteristics and therapeutic goals, rather than assuming that one type of exercise is appropriate for all individuals with ASD [11; 18; 40]. The choice of exercise should be based on the individual's functional ability, developmental stage, sensory characteristics, therapeutic priorities, accessibility and personal preferences, in addition to the modality label.

The results of this review should be considered a hypothesis for treatment ranks and a goal-oriented approach, and not a final or definitive treatment rank. For instance, aquatic exercise may apply if there is overlap among the three individual goals (motor, sensory, and social), while aerobic exercise may apply if there is overlap in the cardiorespiratory fitness and selected executive function goals. Self-regulation and sensory-related outcomes may warrant yoga, while strength and functional capacity may warrant resistance training [8; 20; 32; 33]. These associations, however, should not be taken as evidence for the superiority of a specific modality for a specific outcome.

Importantly, the apparent multidimensional benefit of aquatic exercise may reflect the number of outcomes measured, rather than the modality itself. Likewise, the reported social benefits of martial arts may be related to the structured and interactive nature of the programmes rather than to the martial arts themselves. Thus, exercise modalities should not be considered as interchangeable; nor should they be ranked by overall effectiveness; rather, characteristics and demands of the intervention, in addition to the individual's needs, should be taken into consideration.

Methodological Heterogeneity, Conflicting Findings, and Critical Appraisal of the Evidence Base. There is considerable heterogeneity among the primary empirical studies, which limits the interpretation of the comparative evidence. The findings are difficult to interpret due to differences in participants' ages, pre-intervention functional ability, symptom presentation, exercise intensity, frequency, intervention duration, intervention setting, and types of outcome measures used. Various study designs were also identified, such as RCTs, quasi-experimental, observational, pilot and qualitative studies. Thus, the results of studies that utilise

different methods or designs should not be equated in their evidentiary weight.

Varied results from other studies impose further restrictions in making generalisations about the effectiveness of exercise. In contrast, the results of aerobic exercise were more consistent for cardiorespiratory fitness and selected executive function outcomes, but were less consistent for social participation and sensorimotor outcomes [1; 8; 11; 14; 18; 47]. Evidence for self-regulation and sensory-related outcomes was clearer for yoga [20; 21; 33; 38] and more limited and focused for resistance training [4; 32; 48]. These differences suggest that the outcome domain is as critical as the exercise modality in determining issues in interpreting evidence.

The methodological quality assessment is used to give background information for these results. In the study-level appraisal, we found some studies had limited or low methodological quality, while a few were of higher methodological quality, as shown in Supplementary Table S1. Small samples, non-randomised designs or studies with methodological limitations must therefore be used with caution rather than more rigorously controlled studies.

Similarly, the qualitative ratings in Table 2 should be interpreted as measures of the range and consistency of the reported findings, not as evidence grades, effect sizes, or the certainty of the evidence. Another limitation is the variation in the exercise categories. For instance, motor requirements, social interaction and pedagogy, as well as intensity of exercise, vary significantly across structured sport and martial arts programmes. Likewise, variations in programme length and exposure to the intervention make it hard to assess whether the observed benefits reflect short- or long-term effects, or occur only within specific intervention protocols. The range and diversity of the outcomes measured, in both number and type, can also be a source of apparent multi-domain benefits.

Overall, the evidence favours a therapeutic-profile approach over prioritising exercise modalities. There are consistent trends across certain outcomes, but to date, there is no evidence that any modality is superior in general. Intervention variability, methodological variation, and findings across domains suggest that conclusions should be proportional to the quality and quantity of the evidence.

Proposed Mechanisms underlying Exercise Benefits in Individuals with ASD. The reviewed literature indicates that the benefits of exercise might not be mediated by a single mechanism but by neurobiological, motor-learning, sensory, cognitive and psychosocial processes. The evidence underpinning these suggested pathways, however, varies significantly by pathway, and few studies have directly explored mechanisms as a mediator between exercise and outcomes in ASD.

Neurobiological and Motor Learning Mechanisms. The changes in neuroplasticity, cerebral blood flow, synaptic adaptation, and neurotrophic factors (such as brain-derived neurotrophic factor (BDNF)) seen with exercise may provide a basis for cognitive and behavioural effects [8; 19; 31; 42]. It is also possible that repeated movement practice, task-specific training and progressive skill acquisition can support the development of balance, coordination, motor planning and functional competence [20; 21; 37].

Mechanisms that can be directly demonstrated in individuals with ASD should be contrasted with mechanisms proposed in the broader exercise-neuroscience literature. Results from the reviewed ASD studies suggest benefits in outcomes and motor-skill processes associated with repeated movement practice, task-specific training, and motor-skill acquisition. By contrast, enhancements in cerebral blood flow, synaptic adaptation, BDNF activity, and neuroplasticity are not directly linked to exercise-related effects in ASD. These neurobiological pathways should therefore be considered potential mechanisms of explanation, not confirmed causal pathways specific to ASD.

Sensory and Psychosocial Mechanisms. Exercise interventions may involve sensory and/or psychosocial processes, which may be important in aquatic exercise, yoga and martial arts [20; 29; 33]. Communication, imitation, cooperation and rule-following may also be encouraged through group activities. The reviewed studies have reported evidence of improvements on some sensory, behavioural and social outcomes but have not provided evidence of the specific processes underlying these improvements.

These mechanisms are difficult to isolate since the exercise interventions often involve multiple active components. For instance, when a group-based martial arts programme is followed, several mechanisms may be operating: physical activity, social interaction, structured instruction, and

repeated motor practice. Improvements observed as a result of this programme can be attributed to one or more of these processes. In the same way, when sensory interventions such as aquatic or mind–body are found to improve a skill or behaviour, it is difficult to determine whether the sensory component of the intervention is responsible for its effectiveness. Sensory and psychosocial mechanisms, therefore, should be treated as plausible or hypothesis-generating in ASD, rather than causal mechanisms.

Integrated Perspective. Overall, the evidence suggests a multidimensional approach to the role of exercise in developmental outcomes, with motor, cognitive, sensory, behavioural and psychosocial processes interrelated in this context [26]. More importantly, the empirical status of these pathways differs. Studies of individuals with ASD report improvements in motor, cognitive, behavioural, sensory and social outcomes [20; 21; 27; 28; 33], while some of the underlying neurobiological mechanisms are extrapolated from the broader exercise-neuroscience literature [19; 31].

It is important, therefore, to view Figure 1 as a model of the proposed pathways and not as a causal model. It is important to separate observed results from proposed explanations when interpreting the evidence. Future studies should directly investigate exercise-associated mechanisms underlying improvements in ASD, using appropriate physiological, neurobiological, behavioural and process measures.

Integrative Interpretation and Contribution of the Review. The present review goes beyond a descriptive summary of exercise interventions and incorporates elements of exercise characteristics, outcome domains, participant characteristics, and methodological quality to pinpoint where exercise interventions converge and diverge in the ASD exercise literature. The results do not provide a ranking of modalities by overall effectiveness; rather, they support interpretation of exercise interventions in relation to their intended goals, participant characteristics, and functional needs.

Importantly, the apparent differences between the exercise modalities should not be viewed in isolation from the evidence limitations reported in this review. The observed pattern of benefits may be affected by variations in participant characteristics, intervention dose, outcome measurement, study design, and methodological quality. Thus, the profiles of modalities identified in this review are not necessarily modality-specific effects but rather patterns in the evidence.

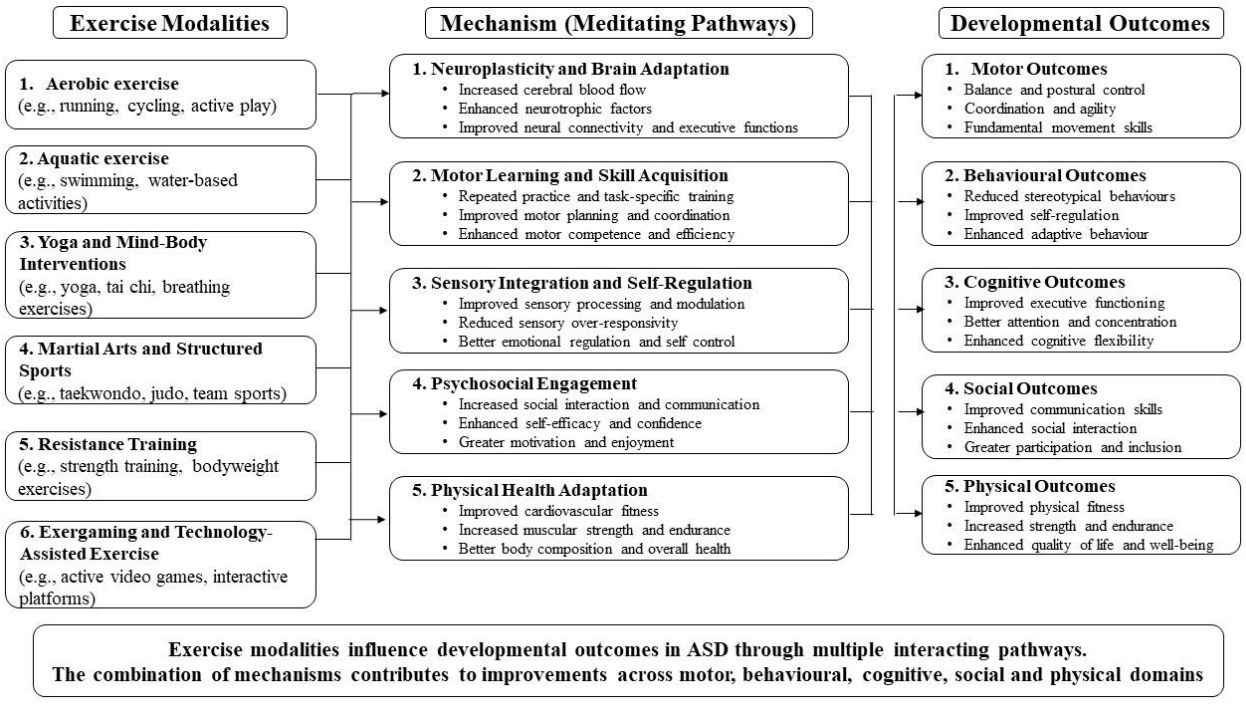

Figure 1. Conceptual Pathways Linking Exercise Modalities to Developmental Outcomes in Individuals with ASD

The purpose of this review is not, therefore, to list the reported benefits of exercise in the context of ASD, but rather to offer a critically contextualised framework for the interpretation of exercise evidence in ASD. This framework can support researchers and practitioners in aligning exercise features with desired outcomes and specific needs and in acknowledging the current evidence-based uncertainty. It also raises the need for well-controlled studies to evaluate whether the differences between the exercise modalities persist when participant characteristics, intervention dose, and outcome measurement are better controlled.

This figure presents a conceptual model of the neurobiological, motor learning, sensory and psychosocial pathways that may contribute to the effects of various exercise modalities. The model differentiates between outcomes supported by data from the ASD literature and those proposed based on the broader exercise-neuroscience literature. Specifically, via the lens of neuroplasticity, increased cerebral blood flow, synaptic adaptation, and BDNF-related activity are discussed as potential mechanisms of exercise in ASD but are not known to be causal mediators. The framework is rooted in the exercise-cognition framework and developmental and motor-learning frameworks [19; 26; 37].

Practical Implications. The comparative results are of significance for research-to-practice translation. Clinicians, educators, families, and community providers should be mindful that a variety of exercise interventions can be adapted to individual characteristics, therapeutic goals, and environmental contexts, rather than seeking a single superior form of exercise. Based on the comparative evidence that was extracted in this review, the following practical implications are suggested to aid the implementation of evidence-informed, person-centred exercise for individuals with ASD.

Implications for clinical and educational practice. The evidence presented in this review supports the use of structured exercise as a complementary intervention in clinical and educational settings for ASD [7; 9; 11; 18]. Exercise programmes should be modified based on the developmental stage, functional ability, sensory characteristics, therapeutic aims and personal preferences of the participants [18; 40; 41]. Evidence-informed exercise programmes may be incorporated into rehabilitation and school-based programmes [11; 41] in collaboration with healthcare professionals, physiotherapists, occupational therapists, adapted physical activity specialists, and educators. In addition to promoting motor competence and physical fitness, organised physical activity can positively affect other areas of functioning, such as behavioural regulation, executive functioning, and social participation, which are important to educational and rehabilitation goals [7; 9; 11; 18; 43].

Family and Community Participation. Families and community groups may play an important role in supporting ongoing physical activity. Caregiver support, encouragement, and involvement may help facilitate adherence and continued engagement in exercise programmes [7; 11; 18]. Accessibility, social inclusion and opportunities to transfer skills learnt in structured programmes into everyday life may be further improved through community-based programmes, such as aquatic programmes, adapted sports, martial arts, and recreational exercises [10; 27; 29]. Therefore, participating in collaboration among families, healthcare providers, schools, and community organisations is necessary to maximise participation and long-term functional outcomes [9; 11].

Recommendations for Individualised Exercise Prescription. Given the comparative evidence presented here, exercise prescription needs to move beyond simply identifying the strengths of each exercise modality and apply these to implement a person-centred exercise programme. It is preferable to individualise exercise interventions for participants' preferences, functional ability, developmental stage, therapeutic objectives, therapeutic programme accessibility and resources, rather than using a generic approach [11; 18; 41]. This is consistent with current guidelines recommending that a personalised exercise prescription for individuals with ASD be integrated into a multidisciplinary treatment programme [9; 40].

Multimodal exercise programmes can be used to achieve multiple developmental goals when appropriate, if complementary intervention elements are included. However, it is not sufficient to include multiple types of exercise; it is also necessary to ensure progressive skill development, enjoyment of the exercise, family participation, and engagement of activities during the intervention [7; 18; 43]. Evidence remains limited

regarding the comparative effects of specific exercise modalities (e.g., resistance training versus aerobic exercise), and adherence appears to be an important factor influencing intervention outcomes [11; 41].

In clinical, educational, family, and community settings, evidence suggests that exercise programmes can be feasible and adapted to person-centred needs, although long-term sustainability remains dependent on accessibility, adherence, and contextual factors. Maximising the number of individuals with ASD who achieve functional independence and health outcomes well into the future will likely involve translating comparative evidence into individualised programmes tailored to changing developmental needs over time [7; 9; 18].

Future Research Directions. Based on the current evidence, there are benefits to exercise-based interventions for individuals with ASD; further uncertainties remain regarding comparative effectiveness, mechanisms, implementation and generalisability. Future studies need to move beyond determining the effectiveness of exercise for participants and explore how to maximise, tailor, and maintain exercise interventions over the longer term.

Personalised and Comparative Exercise Prescription. Further research is needed on the choice of exercises, exercise properties and multimodal combinations that are most suited for certain developmental outcomes in individuals with ASD. The effect of exercise modalities, intensity, frequency, duration, programme characteristics, motor performance, behavioural regulation, cognitive functioning, social participation, sensory outcomes, and physical fitness on various age and functional populations should be systematically studied in comparative effectiveness studies. Responsiveness should also be investigated across developmental stages, motor competence, sensory characteristics, and other relevant participant characteristics. The evidence-informed frameworks developed and planned for testing could help with patient selection for interventions and clinical decision-making.

Mechanisms Underlying Exercise-Induced Benefits. The mechanism underlying how exercise is effective at improving ASD is not fully understood. Future research should integrate neuroimaging, physiological, and traditional behavioural and functional measures with wearable technology to explore neurobiological, motor-learning, sensory, and psychosocial pathways. Importantly, research should go beyond describing associations and test direct mechanisms and/or mediators of exercise-related change in individuals with ASD. This could help clarify mechanisms supported by evidence from the field of ASD compared to those currently extrapolated from exercise-neuroscience research more broadly.

Translation, Technology, and Long-Term Implementation. Implementation research focusing on effective delivery of evidence-informed exercise programmes within healthcare, education and community settings should be prioritised. Future research should assess feasibility, accessibility, adherence, sustainability and cost-effectiveness in real-world settings. The added value of emerging technologies such as exergaming, tele-exercise, wearable activity monitors, virtual reality and digital health platforms should also be considered in terms of their potential to improve participation, ease programme delivery and increase engagement, especially when access to specialist exercise programmes is limited.

Table 3

Priority Areas for Future Research on Exercise Interventions in Individuals with ASD

Research Priority	Key Future Direction
Precision and personalised exercise	Develop individualised exercise prescription models based on participant characteristics.
Comparative effectiveness	Compare exercise modalities and multimodal programmes for specific therapeutic outcomes.
Mechanistic research	Clarify neurobiological, motor-learning, sensory, and psychosocial mechanisms underlying exercise benefits.
Translation into practice	Evaluate implementation strategies, sustainability, adherence, and cost-effectiveness in real-world settings.
Technology-enhanced interventions	Investigate tele-exercise, wearable devices, virtual reality, and digital health technologies.
Global and inclusive research	Expand research across diverse populations, age groups, and low-resource settings.

Inclusive and High-Quality Research. Controlled trials with good power, clearly defined intervention protocols, standardised outcome measures, methodological quality assessment, and longer follow-up should be considered a priority research objective in the future. More representation of adults, females, participants with higher support needs, culturally diverse participants, and participants from low- and middle-income countries will also enhance generalisability and global applicability of exercise recommendations for individuals with ASD. In addition, studies should include sufficient detail on participants and intervention parameters to enable meaningful comparisons and replications across studies.

Strengths and Limitations. Strengths. This structured review is a comprehensive and comparative analysis of the existing evidence on the impact of different types of exercise on motor, behavioural, cognitive, social and physical function in individuals with ASD. The review combines findings from aerobic exercise, aquatic programmes, yoga, martial arts, resistance training, exergaming and multimodal exercise, providing a broader perspective than modality-specific reviews, and enabling it to assess the relative advantages, potential use and clinical relevance of various exercise approaches.

A further advantage of this review is that the evidence is recent, and therefore the synthesis reflects recent developments in exercise-based interventions for ASD. The review also takes into account findings from the studies across different age groups, intervention settings, and functional domains, making it more applicable to clinical, educational, therapeutic, research, and caregiving practitioners. In addition, the structured search strategy, predetermined eligibility criteria and transparent evidence synthesis provide methodological rigour and reproducibility for the review.

Limitations. It is important to note several limitations of the reviewed literature and the present review. There is significant variation across studies in participants' characteristics, exercise modalities, intensity, duration, outcome measures, and methodological quality, making it difficult to directly compare interventions. Secondly, a number of studies were small and therefore lacked statistical power and generalisability of the data reported.

There is also considerable inter-study variability in the definitions of motor competence, behavioural functioning, executive functioning, social participation and the quality of life. Evidence of long-term follow-up is limited and problematic for assessing long-term intervention effects beyond the intervention period. Lastly, there is limited external validity and clinical applicability of current evidence because important populations such as adults, females, individuals with higher support needs, and individuals with co-occurring intellectual disability remain underrepresented in the current literature.

Moreover, the narrative review design does not allow quantitative synthesis or the establishment of causal relationships between the specific exercise modalities and observed outcomes. Instead, the findings of this review are drawn from a critical synthesis and interpretation of the available evidence. The results, therefore, need to be interpreted as evidence-based recommendations rather than causal statements, given the methodological diversity among the included studies.

While there are some limitations, the evidence reviewed generally supports structured exercise as a valuable addition to multidisciplinary care, although it is heterogeneous across exercise modalities and outcome domains. However, it is important to note the methodological limitations of the available literature when interpreting the comparative findings provided in this review.

Moreover, the methodological quality assessment revealed differences among the included primary empirical studies. Several of the RCTs were moderately to well-designed methodologically, whereas others were limited or poorly designed. The results are therefore read with caution, especially in cases where they are based on studies with methodological weaknesses. The quality appraisal provides further context for interpreting the comparative findings, but does not imply that studies with low methodological quality were excluded from the narrative synthesis. Instead, the assessment was intended to increase transparency and recognise the validity of the available evidence.

5. Conclusions

This narrative review synthesised evidence from 46 studies evaluating structured exercise interventions for individuals with ASD. Across the included studies, intervention durations generally ranged from 6 to 24 weeks, with exercise frequencies of 2–5 sessions per week, depending on the modality. Overall, the reviewed literature suggests beneficial effects of structured exercise across several motor, behavioural, cognitive, social, and physical domains, although the consistency and methodological strength of the evidence varied by outcome and exercise modality. Among the exercise modalities reviewed, aquatic exercise showed a relatively broad pattern of reported benefits across multiple outcome domains, whereas aerobic exercise consistently improved cardiorespiratory fitness and executive function. Yoga primarily enhanced self-regulation, sensory processing, and emotional control, while martial arts improved motor coordination, balance, and social interaction. Evidence for resistance training and exergaming was encouraging but comparatively limited, given the small number of available studies.

Despite these positive findings, considerable methodological heterogeneity was observed across studies, including differences in intervention protocols, outcome measures, participant characteristics, and follow-up durations, which limited direct comparisons between exercise modalities. Current evidence supports a goal-oriented, individualised approach to exercise prescription based on functional abilities, therapeutic priorities, and personal preferences, with structured exercise interventions that can be integrated into clinical, educational, and community rehabilitation programmes.

Future research should prioritise well-designed comparative RCTs, standardised outcome measures, and longer follow-up periods, particularly involving adolescents, adults, and individuals requiring higher levels of support, to strengthen the evidence base and facilitate precision exercise prescription for ASD.

Conflicts of interests

The authors declare no conflicts of interest.

Funding

No external funding was received for the preparation of this review article

Declaration of Use of AI

Grammarly was used to support language refinement, grammar correction, and formatting consistency during manuscript preparation. No content or ideas were generated by artificial intelligence tools, and all intellectual work, synthesis and conclusion presented in this manuscript are solely those of the authors.

References

1. Ahmed, M. M., Alawna, M., Youssef, A. S. A., Amin, W. M., Alajam, R. A., Morsy, W. E., Fayed, E., & Ahmed, A. A. M. (2024). Immediate effect of physical activity on the autonomic nervous system in individuals with autism spectrum disorders of different age groups: A randomized trial. *BMJ Open Sport & Exercise Medicine*, *10*, e001822. https://doi.org/10.1136/bmjsem-2023-001822
2. American Psychiatric Association. (2022). *Diagnostic and statistical manual of mental disorders* (5th ed., text rev.; DSM-5-TR). *American Psychiatric Association Publishing*. https://doi.org/10.1176/appi.books.9780890425787
3. Baethge, C., Goldbeck-Wood, S., & Mertens, S. (2019). SANRA – A scale for the quality assessment of narrative review articles. *Research Integrity and Peer Review*, *4*(1), 5. https://doi.org/10.1186/s41073-019-0064-8
4. Beygrezaei, M., & Ofoghi, M. (2024). The effect of eight weeks of central stability exercises on sensory-motor development of children with high-functioning autism spectrum disorder. *Shenakht Journal of Psychology and Psychiatry*, *11*(2), 78–92. https://doi.org/10.32598/shenakht.11.2.78
5. Bhat, A. N., Landa, R. J., & Galloway, J. C. (2011). Current perspectives on motor functioning in infants, children, and adults with autism spectrum disorders. *Physical Therapy*, *91*(7), 1116–1129. https://doi.org/10.2522/ptj.20100294
6. Bremer, E., Balogh, R., & Lloyd, M. (2015). Effectiveness of a fundamental motor skill intervention for 4-year-old children with autism spectrum disorder: A pilot study. *Autism*, *19*(8), 980–991. https://doi.org/10.1177/1362361314557548
7. Bremer, E., Crozier, M., & Lloyd, M. (2016). A systematic review of the behavioural outcomes following exercise interventions for children and youth with autism spectrum disorder. *Autism*, *20*(8), 899–915. https://doi.org/10.1177/1362361315616002
8. Bremer, E., Graham, J. D., Heisz, J. J., & Cairney, J. (2020). Effect of acute exercise on prefrontal oxygenation and inhibitory control among male children with autism spectrum disorder: An exploratory study. *Frontiers in Behavioral Neuroscience*, *14*, 84. https://doi.org/10.3389/fnbeh.2020.00084

9. Cai, B., Miao, Y., Zhao, J., Ying, X., & Lin, W. (2025). The effect of exercise intervention on cognitive function and quality of life with autism spectrum disorder: A systematic review and meta-analysis. *Actas Espanolas de Psiquiatria*, *53*(4), 839–856. https://doi.org/10.62641/aep.v53i4.2040
10. Cai, K., Wang, J., Liu, Z., Zhu, L., Xiong, X., Klich, S., Maszczyk, A., & Chen, A. (2020). Mini-basketball training program improves physical fitness and social communication in preschool children with autism spectrum disorders. *Journal of Human Kinetics*, *73*(1), 267–278. https://doi.org/10.2478/hukin-2020-0007
11. Craig, D. W. (2022). Examining the effectiveness of physical activity interventions for children with autism spectrum disorders: A systematic review. *Journal of Prevention & Intervention in the Community*, *50*(1), 104–115. https://doi.org/10.1080/10852352.2021.1915939
12. Fang, Q., Aiken, C. A., Fang, C., & Pan, Z. (2019). Effects of exergaming on physical and cognitive functions in individuals with autism spectrum disorder: A systematic review. *Games for Health Journal*, *8*(2), 74–84. https://doi.org/10.1089/g4h.2018.0032
13. Faraji, S., Najafabadi, M. G., Zandi, H. G., & Shaw, I. (2023). Effect of aquatic therapy on motor skill and executive function in children with autism spectrum disorder. *South African Journal for Research in Sport, Physical Education and Recreation*, *45*(2), 17–27. https://doi.org/10.36386/sajrsper.v45i2.101
14. Ferreira, J. P., Ghiarone, T., Júnior, C. R. C., Furtado, G. E., Carvalho, H. M., Rodrigues, A. M., & Toscano, C. V. A. (2019). Effects of physical exercise on the stereotyped behavior of children with autism spectrum disorders. *Medicina*, *55*(10), 685. https://doi.org/10.3390/medicina55100685
15. Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism and Developmental Disorders*, *40*(10), 1227–1240. https://doi.org/10.1007/s10803-010-0981-3
16. Fu, X., & Shi, P. (2025). The intervention effect of structured martial arts games on behavioral impairments and motor functions in children with autism spectrum disorder. *Frontiers in Psychology*, *16*, 1660040. https://doi.org/10.3389/fpsyg.2025.1660040
17. Healy, S., Brewer, B., Garcia, J. M., Daly, J., & Patterson, F. (2021). Sweat, sit, sleep: A compositional analysis of 24-hour movement behaviors and body mass index among children with autism spectrum disorder. *Autism Research*, *14*(3), 545–550. https://doi.org/10.1002/aur.2434
18. Healy, S., Nacario, A., Braithwaite, R. E., & Hopper, C. (2018). The effect of physical activity interventions on youth with autism spectrum disorder: A meta-analysis. *Autism Research*, *11*(6), 818–833. https://doi.org/10.1002/aur.1955
19. Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: Exercise effects on brain and cognition. *Nature Reviews Neuroscience*, *9*(1), 58–65. https://doi.org/10.1038/nrn2298
20. Ju, X., Liu, H., Xu, J., Hu, B., Jin, Y., & Lu, C. (2024). Effect of yoga intervention on problem behavior and motor coordination in children with autism. *Behavioral Sciences*, *14*(2), 116. https://doi.org/10.3390/bs14020116
21. Kaur, M., & Bhat, A. (2019). Creative yoga intervention improves motor and imitation skills of children with autism spectrum disorder. *Physical Therapy*, *99*(11), 1520–1534. https://doi.org/10.1093/ptj/pzz115
22. Kolb, B., & Gibb, R. (2011). Brain plasticity and behaviour in the developing brain. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *20*(4), 265–276.
23. Kou, R., Zhang, Z., Zhu, F., Tang, Y., & Li, Z. (2024). Effects of exergaming on executive function and motor ability in children: A systematic review and meta-analysis. *PLOS ONE*, *19*(9), e0309462. https://doi.org/10.1371/journal.pone.0309462
24. Kurtoglu, A. E., Çar, B., Konar, N., Uzgur, K., & Baltaci, O. (2023). Investigation of the effect of eight-week aqua fitness exercises on some strength parameters and body composition in individuals with autism spectrum disorder. *International Journal of Disabilities Sports & Health Sciences*, *6*(3), 279–286. https://doi.org/10.33438/ijdshs.1254879
25. Leonard, H. C., & Hill, E. L. (2014). Review: The impact of motor development on typical and atypical social cognition and language. *Child and Adolescent Mental Health*, *19*(3), 163–170. https://doi.org/10.1111/camh.12055
26. Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M., Nilsson, M., Kelly, P., Smith, J., Raine, L., & Biddle, S. (2016). Physical Activity for Cognitive and Mental Health in Youth: A Systematic Review of Mechanisms. *Pediatrics*, *138*(3), e20161642. https://doi.org/10.1542/peds.2016-1642
27. Mok, K., Sze, C. H. H., Yu, C., Mak, E., Chan, D., & Wong, S. W. L. (2024). A self-narrative study: Changes in physical ability and social communication in children with autism through taekwondo training with elements of music therapy from parents' perspective. *Behavioral Sciences*, *14*(7), 530. https://doi.org/10.3390/bs14070530
28. Musiyenko, O., Chopyk, R., & Kizlo, N. (2020). Influence of swimming on sensory functioning, quality of life and behavior of children with autism. *Health, Sport, Rehabilitation*, *6*(3), 60–69. https://doi.org/10.34142/hsr.2020.06.03.07
29. Pan C. Y. (2010). Effects of water exercise swimming program on aquatic skills and social behaviors in children with autism spectrum disorders. *Autism*, *14*(1), 9–28. https://doi.org/10.1177/1362361309339496
30. Pierantozzi, E., Morales, J., Fukuda, D. H., Garcia, V., Gómez, A. M., Guerra-Balic, M., & Carballeira, E. (2022). Effects of a long-term adapted judo program on the health-related physical fitness of children with autism spectrum disorder. *International Journal of Environmental Research and Public Health*, *19*(24), 16731. https://doi.org/10.3390/ijerph192416731
31. Ratey, J. J., & Loehr, J. E. (2011). The positive impact of physical activity on cognition during adulthood: A review of underlying mechanisms, evidence and

recommendations. *Reviews in the Neurosciences, 22*(2), 171–185. https://doi.org/10.1515/RNS.2011.017

32. Ren, J., & Xiao, H. (2024). The intervention effect of progressive exercise training on children with autism spectrum disorder. *International Journal of Sports Science and Physical Education, 9*(1), 1–6. https://doi.org/10.11648/ijsspe.20240901.11
33. Rostami, S., Fayazmilani, R., & Yarani, E. (2025). Effectiveness of yoga training on health-related physical fitness and balance in children with autism spectrum disorder. *Sport Sciences for Health, 21*, 1653–1661. https://doi.org/10.1007/s11332-025-01391-0
34. Ruggeri, A., Dancel, A., Johnson, R., & Sargent, B. (2020). The effect of motor and physical activity intervention on motor outcomes of children with autism spectrum disorder: A systematic review. *Autism, 24*(3), 544–568. https://doi.org/10.1177/1362361319885215
35. Santos, M. S. D., Pereira, A. K. D. O., Soares, S. R. D. C., Carlos, B. L., & Alves, R. D. S. (2025). Exergaming: impact on aerobic capacity and manual strength in autism spectrum disorder. *Revista Neurociências, 33*, 1–22. https://doi.org/10.34024/rnc.2025.v33.20522
36. Savage, M. N., Tomaszewski, B. T., & Hume, K. (2022). Step it up: Increasing physical activity for adults with autism spectrum disorder and intellectual disability using supported self-management and Fitbit technology. *Focus on Autism and Other Developmental Disabilities, 37*(3), 146–157. https://doi.org/10.1177/10883576211073700
37. Schmidt, R. A., & Lee, T. D. (2019). *Motor learning and performance: From principles to application* (6th ed.). Human Kinetics.
38. Shanker, S., & Pradhan, B. (2022). Effect of yoga on the motor proficiency of children with autism spectrum disorder and the feasibility of its inclusion in special school environments. *Adapted Physical Activity Quarterly, 39*(2), 247–267. https://doi.org/10.1123/apaq.2021-0108
39. Shanok, N. A., & Sotelo, M. (2022). A pilot tennis program for training fitness and social behaviours in individuals with autism spectrum disorder. *Journal of Sports Medicine and Physical Fitness, 62*(8), 1118–1126. https://doi.org/10.23736/s0022-4707.21.12414-4
40. Sowa, M., & Meulenbroek, R. (2012). Effects of physical exercise on autism spectrum disorders: A meta-analysis. *Research in Autism Spectrum Disorders, 6*(1), 46–57. https://doi.org/10.1016/j.rasd.2011.09.001
41. Srinivasan, S. M., & Bubela, D. J. (2025). Movement-based interventions. In P. Sturmey, R. Lang, & J. K. Luiselli (Eds.), *Lifespan treatment for autistic individuals: A guide to evidence-based practices* (Chapter 25). Oxford University Press. https://doi.org/10.1093/oso/9780197635841.003.0025
42. Tan, B. W., Pooley, J. A., & Speelman, C. P. (2016). A meta-analytic review of the efficacy of physical exercise interventions on cognition in individuals with autism spectrum disorder and ADHD. *Journal of Autism and Developmental Disorders, 46*(9), 3126–3143. https://doi.org/10.1007/s10803-016-2854-x
43. Toscano, C. V. A., Ferreira, J. P., Quinaud, R. T., Silva, K. M. N., Carvalho, H. M., & Gaspar, J. M. (2022). Exercise improves the social and behavioral skills of children and adolescents with autism spectrum disorders. *Frontiers in Psychiatry, 13*, Article 1027799. https://doi.org/10.3389/fpsyt.2022.1027799
44. Toscano, C. V., Carvalho, H. M., & Ferreira, J. P. (2018). Exercise effects for children with autism spectrum disorder: Metabolic health, autistic traits, and quality of life. *Perceptual and Motor Skills, 125*(1), 126–146. https://doi.org/10.1177/0031512517743823
45. Wilson, R. B., McCracken, J. T., Rinehart, N. J., & Jeste, S. S. (2018). What's missing in autism spectrum disorder motor assessments? *Journal of Neurodevelopmental Disorders, 10*, Article 33. https://doi.org/10.1186/s11689-018-9257-6
46. Xing, Y., Liu, H., & Wu, X. (2024). Acquisition and retention effects of fundamental movement skills on physical activity and health-related fitness of children with autism spectrum disorder. *Healthcare, 12*(13), 1304. https://doi.org/10.3390/healthcare12131304
47. Yang, J., & Li, R. (2025). Systematic review and randomized controlled trial meta-analysis of the effects of physical activity interventions and their components on repetitive stereotyped behaviors in patients with autism spectrum disorder. *Frontiers in Psychology, 16*, 1579345. https://doi.org/10.3389/fpsyg.2025.1579345
48. Ye, Q., Hu, G.-Y., Cai, Y.-B., Zhang, G.-W., Xu, K., Qu, T., & Gao, R. (2019). Structural exercise-based intervention for health problems in individuals with autism spectrum disorders: A pilot study. *European Review for Medical and Pharmacological Sciences, 23*(10), 4313–4320. https://doi.org/10.26355/eurrev_201905_17937