

Impact of physical exercise on behavioral and social features in individuals with autism spectrum disorder

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Abstract

Background and Study Aim Physical exercise is linked with several physical and psychological health advantages. A range of investigations has revealed the presence of a significant association between physical exercise and indicative improvements in subjects with Autism Spectrum Disorder (ASD). This systematic review aims to update the literature about the impact of physical exercise interventions on social, behavioral, and other outcomes for individuals with ASD.

Material and Methods The study design followed the PRISMA guidelines. A systematic search of electronic databases—PubMed, Google Scholar, Science Direct, and Jane Publications—was performed from 2010 to December 2023. We searched for related research papers in English using keywords 'Autism Spectrum Disorder,' 'exercise,' and 'physical activity.'

Results This systematic review employed a four-stage screening process, which resulted in the inclusion of 18 trial studies. The intervention period varied from three to forty-eight weeks, with a frequency of 3-7 times per week. The results demonstrated that physical exercise had a substantial positive impact on communication, social interaction, and motor skills in subjects with Autism Spectrum Disorder (ASD).

Conclusions This review supports physical exercise as a powerful tool in decreasing stereotypical behaviors, and in improving social communication and motor skills in subjects diagnosed with ASD. Regular physical exercise therapy can have a greater effect on improving the quality of life for ASD subjects.

Keywords: autism spectrum disorder, exercise, physical activity, psychological, health

Introduction

Autism Spectrum Disorder (ASD) is a multifactorial neurodevelopmental disorder typically identified at a very early age and usually persists throughout an individual's life. The hallmark symptoms of ASD include impaired speech skills, limited social engagement, and repetitive behaviors. The etiology of ASD remains largely unknown, and effective preventive measures have yet to be established [1]. Currently, no reliable early diagnostic biomarkers or definitive treatments are available for individuals with ASD [2]. While a limited number of treatment options exist, the therapeutic outcomes of various rehabilitation methods vary significantly, posing a considerable financial burden on the families of ASD patients and on social service systems [3].

Various behavioral intervention programs aimed at developing social, communication, and cognitive skills have been implemented, leading to positive outcomes for individuals with Autism Spectrum Disorder (ASD). Recent research suggests that

incorporating therapeutic options such as exercise, sports, and additional physical activities alongside traditional behavioral therapies can significantly benefit the improvement of behavioral symptoms and the quality of life in individuals with ASD [4, 5, 6].

A variety of exercise programs, such as swimming, jogging, roller-skating, hydrotherapy, walking, cycling, weight training, horse riding, and exergames, have been implemented in individuals with ASD to mitigate the frequency of stereotypical behaviors [4, 7, 8], reduce hyperactivity, and address aggressive or self-injurious behaviors [9]. Hydrotherapy and horse riding therapies, in particular, aim to enhance balance and gross motor coordination in children with autism. Furthermore, these interventions have been utilized to curtail aggressive and antisocial behaviors, thereby improving social engagement and interpersonal relations in individuals with ASD [10, 11]. There is a robust body of research confirming the significant role of exercise therapies in enhancing behavioral, social, and motor skills in individuals with ASD [4, 12, 13]. Additionally, engagement in physical activities has been shown to bolster communication abilities,

balance, and overall fitness levels in subjects with ASD [14, 15].

The benefits of physical exercise, including enhancements in cardiorespiratory function [6], motor skill performance [16], muscular strength [12], and a decrease in body mass index [17], have been well-documented for individuals with ASD. Overall, exercise plays a pivotal role in both physical and mental health, offering a holistic approach to well-being. Physical activities that engage both the body and mind have been shown to reduce stereotypical behaviors and improve cognitive functions [18] and perceptual-motor skills [19] in individuals with ASD. Additionally, exercise therapy has been effective in alleviating stress and anxiety, reducing reaction times, enhancing memory, and improving sleep quality [20].

In recent years, a multitude of review articles has emerged, examining the impact of exercise on various aspects, including social communication [21], the immune, musculoskeletal, and gut systems [22], stereotyped behaviors [23, 24], as well as academic and physical activity outcomes [25] in subjects with ASD.

Despite growing evidence supporting the behavioral and mental health benefits of physical exercise, research specifically addressing individuals with ASD remains limited. The clarity of outcomes from various studies is often obscured by significant variations in sample sizes, intervention durations, frequencies, and measurement methods. The primary objective of this systematic review is to update the existing literature on the effects of physical exercise interventions on social, behavioral, and other outcomes in individuals with ASD.

Methodology

Search Strategy

Search strategies adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [26]. This review considered all relevant research articles published in peer-reviewed journals between 2010 and 2023, focusing on the impact of physical exercise on individuals with ASD, and were available in English. A systematic electronic search was conducted across PubMed, Google Scholar, Science Direct, and Jane publications. Using keywords 'Autism Spectrum Disorder' and 'physical exercise/activity,' we identified 60 pertinent papers. The articles were initially selected based on their titles and abstracts, with a final selection made after a full-text assessment.

Data Collection and Extraction

Two independent researchers systematically extracted data from all selected articles. The following screening methods were employed to determine the relevance of articles from the initial

search to the study objectives:

- a) Topic identification was the first step, after which all duplicate articles were excluded.
- b) The abstracts were assessed for sufficient data pertaining to the research topic, with inadequate articles being removed.
- c) Full texts of the remaining articles were reviewed against the inclusion criteria, and those not meeting these criteria were excluded from the study.
- d) Comprehensive information was extracted from each article, including study reference, number of participants along with their ages, type of intervention, duration, frequency, protocol, and outcomes, as detailed in Table 1.

From the search across Science Direct, Google Scholar, Jane Publication, and PubMed databases, a total of 60 studies were initially identified. After removing duplicates, 33 studies remained. Preliminary screenings of titles and abstracts further narrowed the selection to 28 studies. Ultimately, 18 studies were included in the review following a full-text evaluation (Figure 1).

Study Selection Criteria

The inclusion criteria for selecting studies were as follows:

- a) Participants diagnosed with Autism Spectrum Disorder (ASD) according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) or another recognized diagnostic method, encompassing any age group.
- b) Incorporation of physical exercise as an intervention tool within the study design.
- c) Studies published within the timeframe of 2010 to 2023.

Exclusion criteria for the study selection included:

- 1) Review articles, animal studies, conference proceedings, and duplicate articles.
- 2) Studies that involved subjects with other physical diseases.

Study Characteristics

The key findings from the reviewed articles on this topic are summarized in Table 1. The studies incorporated a variety of exercise approaches—including jogging, running, jumping, ball tapping, cycling, balance trampoline training, games, sports, and more—to assess the impact of physical exercise on individuals with ASD.

Results

Table 1 displays the primary information, intervention characteristics, and outcomes of the included studies. Over the past decade, from 2015 to 2023, nineteen papers were published. These articles collectively involved a total of 870 subjects with ASD, with 757 participants in the ASD-specific groups and 117 in control groups.

Table 1. A summary of published studies examining exercise intervention and relevant outcomes in individuals with ASD

References	Study	No of Subjects (Age in years)	Intervention	Duration	Protocol/ tools	Outcome
1	2	3	4	5	6	7
27	RCT	n= 55 (8–12)	Jogging	30-min daily for 12-week,	Gilliam Autism Rating Scale	Significant improvements in sleep and behavioral functioning
28	RTC	n=27, A=15; C=12; (8-12)	jogging	12-week	Emotion Regulation Checklist and the Child Behavior Checklist	Significant improvement in emotion regulation and reduction in behavioral problems
29		n=20, A=10, C=10, (4 to 7)	Physical exercise	60-min, three times a week for 8 weeks	Abbreviated Development Scale -3	significant improvements in gross motor skills
30	C C T	n=30 (9–12)	Ball-tapping	20 min per session for 24 sessions (two sessions per week,)	video camera and Gilliam Autism Rating Scale (GARS-3)	Hand-flapping stereotypy was significantly reduced
31	Pilot study	n=24, male = 20, female = 4; (11 - 14)	Aerobic, resistive, and neuromuscular	8-week	Body composition and ATEC	Fat mass was significantly reduced, and behavior improved markedly.
32		n=64	Two-wheel cycling vs stationary cycling	-	-	significant improvements in cognition and self-regulation
33	RCT	n= 21, 17 males and 4 females; Mean age = 11.07 ± 1.44	Ball-tapping and jogging	10-min daily for 3 days	stereotypic behavior was videotaped	Hand-flapping, body-rocking and stereotypic behaviors were significantly reduced however, the behavioral benefit diminished at 45 min after the exercise.
34	RCT	n= 64, A = 46, C = 18; (6-12)	Physical Exercise	48-week	Multilevel regression modelling	Beneficial effects on metabolic indicators, autism traits, and parent-perceived quality of life
35	-	n= 20, Adolescents	Motor activities, games and sports	10 weeks	Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)	significant effects on all of the variables except the speed of running and agility
36	RCT	n= 40 (mean = 9.95)	Physical activity	-	-	significant improvements in sleep and in inhibitory control
37		n= 28, A=14, C=14 (Mean: 10.07 ± 0.25)	Running speed and agility, balance, bilateral coordination, and the standing long jump. Handgrip strength (both sides),	Three 60-minute sessions per week for 12 week	of BOT-2, Reaction times, and flexibility tests	Significant improvement in gross motor proficiency with reaction times and flexibility in ASD

Table 1 (continued)

References	Study	No of Subjects (Age in years)	Intervention	Duration	Protocol/ tools	Outcome
1	2	3	4	5	6	7
38	-	n= 10 (mean: 10)	combination of aerobic exercise training and Motor skill training (Ball playing, Balance exercise, Cycle training)	60-minute, thrice-weekly for 3 weeks	sleep-encephalography, parents' questionnaire and standardized test batteries.	sleep efficiency increased, sleep onset latency shortened, and wake time after sleep onset decreased for 63% of the sample, Mood in the morning, improved
39	-	n=66, A=33, C= 33 (13.1 ± 2.97)	Virtual training and physical exercise	One hour 3 times a week for 6 weeks	Executive function tests	Executive functions (working memory, inhibition, flexibility) were improved However, after the intervention stopped, the executive functions decreased
13	RCT	n= 229 (2.3-17.3, mean = 7.8, ±3.2)	Moderate intensity exercise	30 min, twice a week for 48 weeks	Bayesian multilevel regression modelling	Decrease in social interaction problems, attention deficit, emotional reactivity, stereotypical verbal and motor behavior, and sleep disturbances.
40	RCT	n= 112 (4-6)	Games based exercise	1 hour twice a week for 16 weeks.	CAST, AQ-Child	Significant improvement in physical and psychological traits
41		n=16, 3 girls and 13 boys, A=8, C=8 (4-10)	Trampoline training standing long jump without run-up	32 weeks	Motor proficiency BOT2 test	improvement in both the strength of the inferior limbs and motor proficiency
42		n= 25 A=14, C=11 (6.9 ± 2.3)	Trampoline training, standing long jump without run-up	20-32 week	Motor proficiency BOT2 test	Motor pro ciency improved
43	RCT	n = 7, (mean = 13.0 - 1.4)	Aerobic exercise	60 minutes every day for five days	Heart rate (HR) and Borg Rating of Perceived Exertion (RPE)	Significant and large reductions in Stereotypical behaviors in ASD group

A= Autistic, C= Control, ATEC= Autism Treatment Evaluation Checklist, BOT-2=Bruininks-Oseretsky test-2, CAST=The Childhood Autism Spectrum Test, AQ-Child= The Autism Spectrum Quotient-Children's Version, (RCT= Randomized controlled trial, CCT= Controlled Clinical Trial

Regarding the frequency of physical activity, thirteen studies reported engaging in physical activity more than three times per week. Three studies indicated a frequency of physical activity three times or less per week, while the frequency of exercise was not specified in three other studies.

Among the selected papers, nine reported that each physical exercise session lasted between 30 and

60 minutes, and two papers indicated a duration of 10 to 15 minutes. However, the duration of exercise sessions was not specified in the remaining papers. The duration of physical activity interventions varied widely, ranging from 3 weeks to 48 weeks. There were six articles where the intervention period was eight weeks or shorter, and eight papers described interventions extending beyond eight weeks.

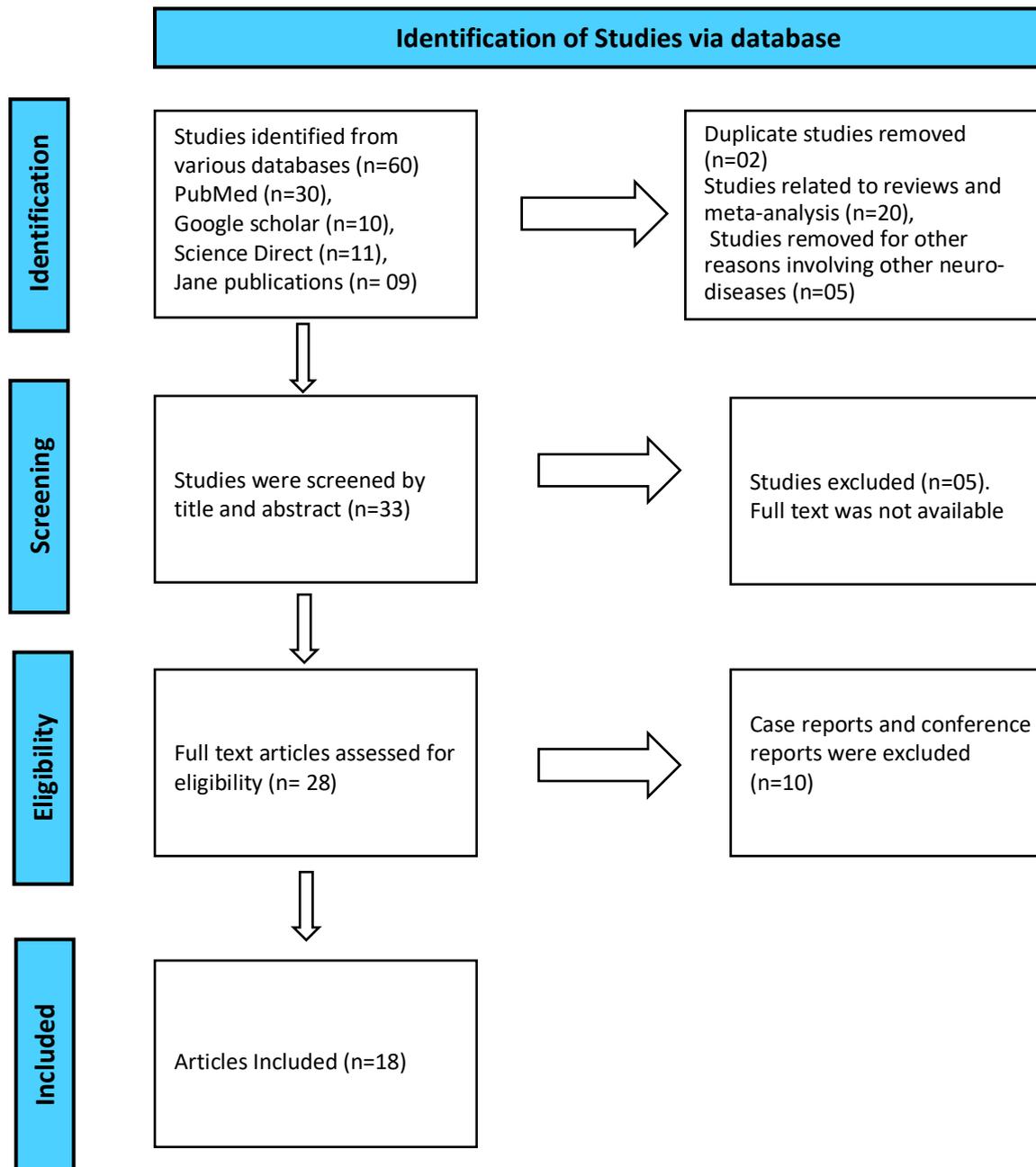


Figure 1. Scheme of information about the different phases of systematic search through the positioning PRISMA guidelines.

The 19 studies reviewed reported various physical exercises, including Jogging (n = 3), Ball playing and balance activities (n = 3), Cycling (n = 2), Aerobic, resistive, neuromuscular, and motor skill exercises (n = 3), Games and sports such as running and standing long jump (n = 2), Trampoline training (n=2), and other physical activities (n = 4). The outcomes of these exercise interventions primarily focused on the three core symptom areas of ASD—stereotypical behaviors, and motor, social, and communication skills—though some studies also explored effects on sleep quality, inhibitory control, emotional regulation, cognitive function, and executive functions.

Geographically, the studies were diverse: five originated from Hong Kong, three from the USA, two each from the UK, Columbia, and Portugal, and the remaining five from Iran, Turkey, China, Brazil, and Switzerland.

Table 1 summarizes all the included studies, detailing physical exercise variables, study type, number of subjects along with their ages, intervention methods, exercise duration, frequency, protocol, and outcomes. Figure 1 presents a flowchart that outlines the four stages of the systematic search process, following the PRISMA statement guidelines.

Discussion

Physical exercise has been employed as an intervention to address various health-related issues in individuals with ASD. The objective of this systematic review was to gather and analyze data from published studies on the impact of physical exercise on stereotypical behaviors, social and cognitive functioning, and physical fitness in subjects with ASD. The outcomes from eighteen studies were assessed through pre- and post-exercise intervention evaluations.

Moderate to Vigorous Physical Activity (MVPA) exercise programs were implemented as interventions for individuals with ASD, engaging them in a variety of activities, including Jogging [27, 28], Ball Playing and Balance [30, 32], Cycling [32, 38], Aerobic Resistive, Neuromuscular, and Motor Skill Exercise [31], Games and Sports like Running and Standing Long Jump [37, 42], Trampoline Training [41, 42], and other physical activities [13, 29, 40].

The studies reviewed herein have shown a significant link between physical exercise and the reduction of stereotypical behaviors [23, 44], along with notable improvements in motor, social, and communication skills [29]. Furthermore, exercise has been observed to positively affect sleep [36, 38], mood, emotion regulation [28], cognition, self-regulation [32], and executive functions [39] in individuals with ASD.

According to this review's findings, in thirteen papers, physical exercise occurred more than three times per week; in three articles, the frequency was three times or less per week; and in two papers, the duration of the intervention was not specified.

Regarding the duration of each physical activity intervention, nine papers reported periods ranging from 30 to 60 minutes, and two papers specified 10 to 15 minutes; the duration in the remaining papers was not clearly defined. The intervention periods for physical activities varied significantly, from 3 weeks to 48 weeks. There were nine papers reporting an intervention period of eight weeks or shorter, and another nine papers documented periods longer than eight weeks.

The frequency, duration, and period of exercise interventions are critical factors influencing the extent and sustainability of their effects [24]. Regarding the optimal duration for interventions, exercises spanning eight to twelve weeks are recommended [21]. Although there is a trend indicating diminishing returns over longer periods, studies have observed only minor differences in the total effect size between moderate and extended exercise durations [21]. Consequently, further research is essential to elucidate the optimal duration of exercise interventions. From the standpoint of session length, engaging in more

than one hour of exercise per session is likely to yield better outcomes. This is particularly relevant for individuals with ASD, where brief periods of exercise may not significantly alter arousal levels or impact brain structure and function. Regarding the frequency of exercise, engaging in physical activities more than three times a week is deemed necessary to produce discernible effects [21]. There is a need for additional studies to investigate whether exercising more than five times per week offers superior benefits compared to a more moderate frequency.

Recent analysis by Su et al. [45] evaluated the impact of exercise interventions, indicating that extended sessions lasting 45–75 minutes, conducted 1–2 times per week for a duration of 12 weeks or more, are necessary to enhance motor skills. Additionally, they found that long-duration exercise sessions are more effective than shorter ones. For significant improvements in psychosocial functioning and to induce neurological changes, interventions should last for at least 50 minutes, 1–2 times per week, over a period of 10 weeks or more [45].

Exercise intensity plays a crucial role in triggering metabolic and associated neurological mechanisms. Lang et al. [9] posited that higher intensity exercise yields more pronounced effects compared to milder forms of exercise. Intensity is commonly gauged by heart rate, and the World Health Organization (WHO) recommends achieving 60–69% of the maximal heart rate (MHR = 220 – participant's age) to qualify as moderate to vigorous physical activity (MVPA) [46]. Conversely, Tse et al. [47] observed that for children with ASD, exceeding 50% of the maximum heart rate (MHR) should be deemed MVPA due to their generally lower levels of physical activity. Given the enhanced benefits of longer-term exercise interventions, maintaining consistent engagement in exercise is vital. It is advisable to gradually attain MVPA, taking into account the individual's perceived exertion rate (RPE), as physical fitness levels vary significantly among individuals.

The outcomes of this review yield several valuable insights. Firstly, exercise interventions may facilitate social integration in individuals with ASD by reducing the duration and intensity of stereotypic behaviors and associated behavioral issues. This could lead to a more positive perception of physical fitness and healthy living among individuals with ASD and their families. Secondly, physical exercise interventions could serve as a preventative behavioral therapy, offering an effective alternative to medications for mitigating maladaptive behaviors. Lastly, as an indirect practical implication, physical exercise is associated with mitigating several health comorbidities prevalent among individuals with ASD, such as those related to higher instances and increased risk of obesity [48] and enhancements in

metabolic health [34].

Physical exercise plays a remarkable role in benefiting both the brain and body. According to heart-brain physiology, an increase in heart rate leads to more oxygen being delivered to the brain and a rise in hormones that support the healthy development of neurons and glial cells. Beyond fostering the growth of new brain cells, exercise enhances brain plasticity and stimulates new connections between the cerebral hemispheres. Aerobic exercises, in particular, impact the overall brain size and improve cognitive functions. Continuous aerobic activity is linked to growth in the hippocampus—the brain structure responsible for emotion regulation, memory, motivation, and overall learning abilities [49]. Many children with ASD, who experience challenges with short-term memory, have seen significant enhancements in hippocampal function and quality of life through aerobic exercise [50].

Various theories have proposed different mechanisms by which exercise ameliorates the principal symptoms of ASD, with regulation of metabolism highlighted as a key process. This metabolic regulation is crucial for transporting trophic factors and neurotransmitters [5, 52, 53], which may contribute to the alleviation of ASD's behavioral symptoms by normalizing brain function.

During physical activity, an increase in heart rate and breathing rate not only delivers more oxygen and nutrients to the muscles and organs but also enhances blood flow. This augmented circulation helps in the removal of waste products, such as lactic acid and carbon dioxide, that accumulate during exercise.

In the brain, physical activity triggers the release of various neurotransmitters and hormones, such as endorphins, serotonin, and dopamine, which are known to enhance mood and alleviate stress. Furthermore, exercise promotes neurogenesis and improves neural connectivity across different brain regions, contributing to enhanced cognitive functions.

This study enriches the existing body of research and clinical understanding within the field of ASD by deepening insights into the relationship between ASD and exercise interventions. The findings from this review will be instrumental in determining which exercises are most beneficial and suitable for individuals with ASD. Additionally, it sets forth several directions for future research, including: (a) evaluating the long-term impacts of physical activity; (b) elucidating the physiological or psychological mechanisms driving, contributing to, or hindering positive outcomes; and (c) discovering effective strategies for integrating exercise into daily routines and existing therapeutic interventions.

The paramount objective of this review is to pave the way for more personalized exercise programs, tailored to the unique needs of individuals with ASD. We are optimistic that the insights gained from this review will positively influence one of the most challenging public health issues faced globally. To comprehensively understand the role of various physical exercise programs in treating children with ASD, further experimental studies involving a larger cohort of ASD subjects are essential, with a particular emphasis on holistic outcomes.

Conclusions

Physical exercise emerges as a promising therapeutic strategy for individuals with ASD, offering diverse benefits across physical, cognitive, and social domains. Research has demonstrated that exercise can enhance physical fitness, motor skills, social interactions, and cognitive performance in the ASD population. Furthermore, it contributes to reducing symptoms of anxiety, depression, and sleep disturbances among these individuals. Optimal outcomes from exercise interventions are typically observed with early initiation, incorporating multi-component exercises, and employing protocols that feature moderate to high intensity, high frequency, prolonged duration, and group settings.

Effective collaboration between healthcare professionals and exercise experts is essential to devise comprehensive exercise programs tailored to the specific needs of individuals with ASD. These programs should consider all aspects of a patient's profile, including physical capabilities and interests, to ensure that the exercise regimen is not only appropriate but also enjoyable and sustainable over time. Further research is necessary to identify which types of exercise interventions are most effective in supporting individuals with ASD, paving the way for more targeted and beneficial therapies.

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Conflict of Interest

The authors have no conflicts of interest to report.

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