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ORIGINAL PAPER

NEURODEVELOPMENTAL AND PHYSICAL THERAPY APPROACHES FOR IMPROVING MOTOR COORDINATION AND PHYSICAL ACTIVITY ENGAGEMENT IN CHILDREN WITH AUTISM SPECTRUM DISORDER: EVIDENCE FROM A CASE SERIES

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Summary

Background. Children with autism spectrum disorder (ASD) frequently present with motor coordination difficulties that hinder daily functioning, social participation, and physical activity engagement. Integrating structured physical therapy interventions into multidisciplinary care may promote motor development and adaptive behavior in this population.

Material and methods. This case series included five children aged 7-11 years with clinically confirmed ASD who participated in a 16-week structured physical rehabilitation program. Sessions (four per week) incorporated balance, locomotor, and coordination exercises tailored to individual profiles. Outcomes were assessed using the Test of Gross Motor Development (TGMD), behavioral rating scales, and the Godin-Shephard Leisure-Time Exercise Questionnaire (GLTEQ).

Results. All the participants demonstrated observable improvements in the TGMD scores, with descriptive patterns indicating enhanced locomotor and object control abilities across the 16-week period. Descriptive behavioral profiles illustrated reductions in maladaptive manifestations and gradual improvements in social-communication and adaptive skills for each child.

Conclusions. This case series describes observable improvements in motor coordination, physical activity participation, and adaptive behaviors following an individualized physical rehabilitation program. Incorporating such programs into multidisciplinary rehabilitation may contribute to improved functional independence and social inclusion.

Keywords: autism spectrum disorder, motor skills, exercise therapy, physical therapy modalities, rehabilitation

Introduction

Autism spectrum disorder (ASD) is a heterogeneous neurodevelopmental condition characterized by persistent difficulties in social communication and interaction, along with restricted and repetitive patterns of behavior, interests, and activities [1]. Global epidemiological data demonstrate a rising prevalence of ASD; the World Health Organization (WHO) estimates that approximately 1 in 100 children worldwide is affected, a figure that has increased steadily over

the past two decades [2,3]. Children with ASD frequently present with co-occurring impairments beyond the core diagnostic criteria, including motor coordination deficits, reduced balance, and altered spatial awareness [4-6]. These difficulties can impede participation in everyday activities, limit access to inclusive education, and negatively affect long-term functional outcomes [7].

Growing evidence supports the need for comprehensive, multidisciplinary interventions that address the diverse cognitive, behavioral, and physical challenges associated with ASD [8]. Historically, rehabilitation programs have tended to emphasize behavioral modification and communication training; while these remain essential, the role of physical therapy and structured motor training has received comparatively less attention despite mounting evidence of its benefits [9,10]. Studies indicate that appropriately designed physical activity interventions can improve gross and fine motor skills, enhance social engagement, and support overall quality of life for children with ASD [11-14]. For example, meta-analyses by Bremer et al. [11] and Healy et al. [12] demonstrated positive changes in balance, coordination, and adaptive behaviors following regular, structured exercise.

Despite this evidence base, access to specialized rehabilitation services remains uneven. In many countries, shortages of trained professionals, insufficient institutional capacity, and limited implementation of inclusive educational policies constrain opportunities for children with ASD to receive comprehensive, affordable therapy [15,16]. This gap underscores the need for evidence-based, individualized interventions tailored to the sensory, cognitive, and behavioral profiles of each child [17,18]. Physical rehabilitation programs that integrate behavioral support, verbal communication training, and structured activities designed to develop balance and spatial orientation have been shown to enhance both motor performance and social functioning [19-21]. Such programs align with the growing consensus that motor skill development is not merely ancillary but integral to broader developmental outcomes in ASD [22].

The present study responds to these challenges by designing and implementing a physical rehabilitation program grounded in scientific and methodological principles aimed at improving motor skills and physical activity levels in children with ASD. Drawing on contemporary evidence, the program incorporates balance training, spatial orientation exercises, and structured play within a multidisciplinary framework. The overarching goal is to foster improvements in motor function, social interaction, and overall well-being, thereby supporting children’s inclusion in educational and community settings [11,12,23].

Motor skill development has emerged as a central focus of contemporary autism research because gross and fine motor impairments are strongly associated with limitations in adaptive functioning, academic achievement, and social participation [4,6,22]. Difficulties with postural control, gait, and bilateral coordination not only restrict children's engagement in physical play but can also exacerbate social isolation and behavioral challenges [7,13]. Recent neuroimaging and developmental studies suggest that atypical connectivity between cerebellar and cortical motor networks may underlie many of these deficits [11], reinforcing the need for early and sustained intervention targeting motor skills.

Evidence-based physical therapy approaches for children with ASD include structured exercise, task-oriented training, aquatic therapy, adapted sports, and sensorimotor integration activities [9,11,17]. These modalities have been shown to improve balance, coordination, cardiovascular fitness, and self-regulation, while also providing opportunities for social interaction and communication practice [10-14,18]. For example, Rosales [17] demonstrated that a water-exercise swimming program showed improvement in aquatic skills and social behaviors in children with ASD, and Todd and Reid [19] reported gains in social competence following a combined sport and recreation intervention. Such findings support the integration of physical therapy into comprehensive rehabilitation programs that also address communication, cognitive, and behavioral domains.

Despite these promising outcomes, many existing programs apply generalized therapeutic methods that fail to account for the heterogeneity of motor, sensory, and cognitive profiles among children with ASD [15,16]. This limits the effectiveness of interventions and underscores the need for research-driven, individualized rehabilitation strategies [17,20]. Programs grounded in functional assessment and personalized goal-setting are more likely to produce sustained improvements in both motor performance and broader developmental outcomes [21,23].

Current evidence demonstrates that structured motor and physical activity interventions can improve motor coordination, adaptive skills, and behavioral regulation in children with autism ASD, yet a significant gap persists in the development of individualized rehabilitation approaches [11,12]. Many studies continue to use standardized, uniform rehabilitation protocols that overlook the pronounced heterogeneity in sensory processing, motor impairments, cognitive function, and behavioral profiles in ASD, thereby limiting treatment precision and effectiveness [24]. Comprehensive baseline profiling and individualized goal-setting are rarely incorporated, despite

evidence that tailored interventions improve engagement, motor learning, and functional independence. Additionally, few investigations integrate personalized physical therapy with broader behavioral or social-communication targets within coordinated multidisciplinary models. Collectively, the absence of rigorous individualized frameworks constitutes a major gap in ASD rehabilitation research and underscores the need for robust studies evaluating personalized, multi-domain interventions capable of addressing the full complexity of ASD-related functional challenges [25].

Although motor- and activity-based interventions show benefits for coordination, adaptive functioning, and behavior in children with ASD, current rehabilitation research remains largely protocol-driven rather than being individualized [11]. Standardized randomized controlled trials (RCTs), while rigorous, emphasize group-level effects and insufficiently account for the marked sensory, cognitive, motor, and behavioral heterogeneity characteristic of ASD [24]. Evidence increasingly shows that individualized, assessment-driven approaches yield better engagement and more meaningful functional gains than uniform protocols [12,24]. Case-series methodology addresses this gap by enabling detailed profiling, flexible adaptation, and granular observation of individual responses, thereby complementing RCT evidence and strengthening the translational relevance of ASD rehabilitation research [25].

Although numerous studies demonstrate that motor-based interventions can benefit children with ASD, most available programs apply uniform treatment protocols that are not tailored to individual differences in motor proficiency, sensory reactivity, or behavioral regulation. This limits the applicability of such interventions to daily clinical practice, where children present with highly variable profiles requiring individualized planning and adjustment. Moreover, the dominance of RCT-based evidence leaves limited understanding of how children respond to personalized therapeutic progressions over time. Recognizing these limitations, the present study aims to systematically document the effects of a 16-week individualized physical rehabilitation program through a case-series design, thereby generating clinically relevant evidence that clarifies how tailored interventions can support meaningful improvements in motor skills, adaptive behaviors, and social functioning among children with ASD.

Aim of the work

The present study seeks to address these gaps by developing and implementing a novel physical rehabilitation program specifically tailored to the needs of children with ASD. The program is built upon three key methodological principles: (1) a comprehensive, multidisciplinary approach that integrates social, psychological, pedagogical, and physical therapy methods; (2) systematic identification of the physical and cognitive characteristics of each child to inform individualized intervention plans; and (3) the use of evidence-based strategies to optimize motor coordination, balance, and spatial orientation. By embedding these principles within an inclusive educational context, the program aims to enhance functional independence and support greater participation in community life [25-27].

The anticipated contributions of this work are both theoretical and practical. From a theoretical perspective, it extends current understanding of the relationship between motor skill development and broader adaptive functioning in children with ASD. Practically, the program offers a replicable model for multidisciplinary rehabilitation that can be adapted for use in schools, clinics, and community settings with limited resources. Methodological recommendations derived from the study are intended for application by parents, educators, therapists, and policy makers seeking to improve the quality and accessibility of rehabilitation services for children with ASD [15,16,19,25]. In this way, the study addresses a pressing public-health and educational priority: ensuring that children with ASD receive comprehensive, evidence-based support to achieve their full potential.

Material and methods

Study setting and participants

This study was conducted at the “XS” Impulse Rehabilitation Center in Yerevan, Armenia. Five children aged 7-11 years with clinically confirmed ASD participated in the research (Table 1). Participants were recruited on a voluntary basis following written parental consent. Each child’s diagnosis was confirmed by a licensed specialist using standard diagnostic criteria.

Table 1. Participant demographics

Participant ID	Age (years)	Gender	Diagnosis	Height (cm)	Weight (kg)	Comorbid conditions
P1	7	Male	Moderate ASD	120	25	None
P2	8	Female	Severe ASD	115	22	Epilepsy, sensory issues
P3	9	Male	Mild ASD	128	30	Orthopedic issues
P4	10	Male	Moderate ASD	130	32	Hyperactivity
P5	11	Female	Severe ASD	118	24	Visual impairment

Inclusion and exclusion criteria

Eligibility criteria were defined to ensure the safety and appropriateness of the intervention program (Table 2).

Table 2. Inclusion and exclusion criteria

Criteria type	Description
Inclusion	Clinical diagnosis of ASD confirmed by a licensed specialist
Inclusion	Age between 7 and 11 years
Inclusion	Parental consent to participate
Exclusion	Uncontrolled epilepsy or frequent seizures during the past 6 months
Exclusion	Severe physical impairments preventing participation in movement-based activities

To improve clinical transparency and contextualize baseline functional levels, information on participants' prior therapeutic and educational interventions was collected through parent interviews. Parents were asked to report all previous and ongoing services their child had received, including speech and language therapy, occupational therapy, behavioral interventions (such as Applied Behavior Analysis or structured behavioral programs), special education support, sensory integration therapy, and any additional rehabilitation or psychological services. Details regarding frequency, duration, and perceived effectiveness of these interventions were documented when available. This information was used to understand each child's therapeutic history and developmental trajectory prior to enrollment in the current program. Documenting prior intervention exposure allowed the research team to better interpret baseline capabilities, adjust individualized rehabilitation plans, and distinguish newly acquired skills during the study period from those potentially influenced by earlier therapies.

Preliminary assessment and data collection

Parental questionnaire

Prior to program initiation, parents completed a detailed questionnaire designed to collect demographic data, developmental history, comorbidities, medication use, and relevant behavioral characteristics. The questionnaire included sections on central nervous system disorders, orthopedic conditions, sensory impairments, and other health concerns to ensure individualized safety and program adaptation. Parents were also asked to specify motivational strategies (e.g. preferred reinforcement items, activities, or sensory stimuli) to support behavioral engagement during sessions.

Behavioral assessment

Autistic behaviors were assessed using a custom instrument adapted from established tools such as the Autism Diagnostic Observation Schedule (ADOS) [28], the Autism Treatment Evaluation Checklist (ATEC) [29], and the Aberrant Behavior Checklist (ABC) [30]. This assessment was administered at baseline and at the completion of the intervention to evaluate changes in behavioral indicators. Items were rated on a 3-point scale reflecting severity (1 = mild, 2 = moderate, 3 = severe). Total scores allowed classification of ASD symptom severity as mild (11-17 points), moderate (18-24 points), or severe (25-33 points).

Motor skill assessment

Motor development was assessed using a specialized scale measuring gross and fine motor skills prior to the intervention. Physical endurance was rated on a 3-point scale (low, moderate, high endurance) based on the child's ability to complete structured activities of varying duration (Figure 1).

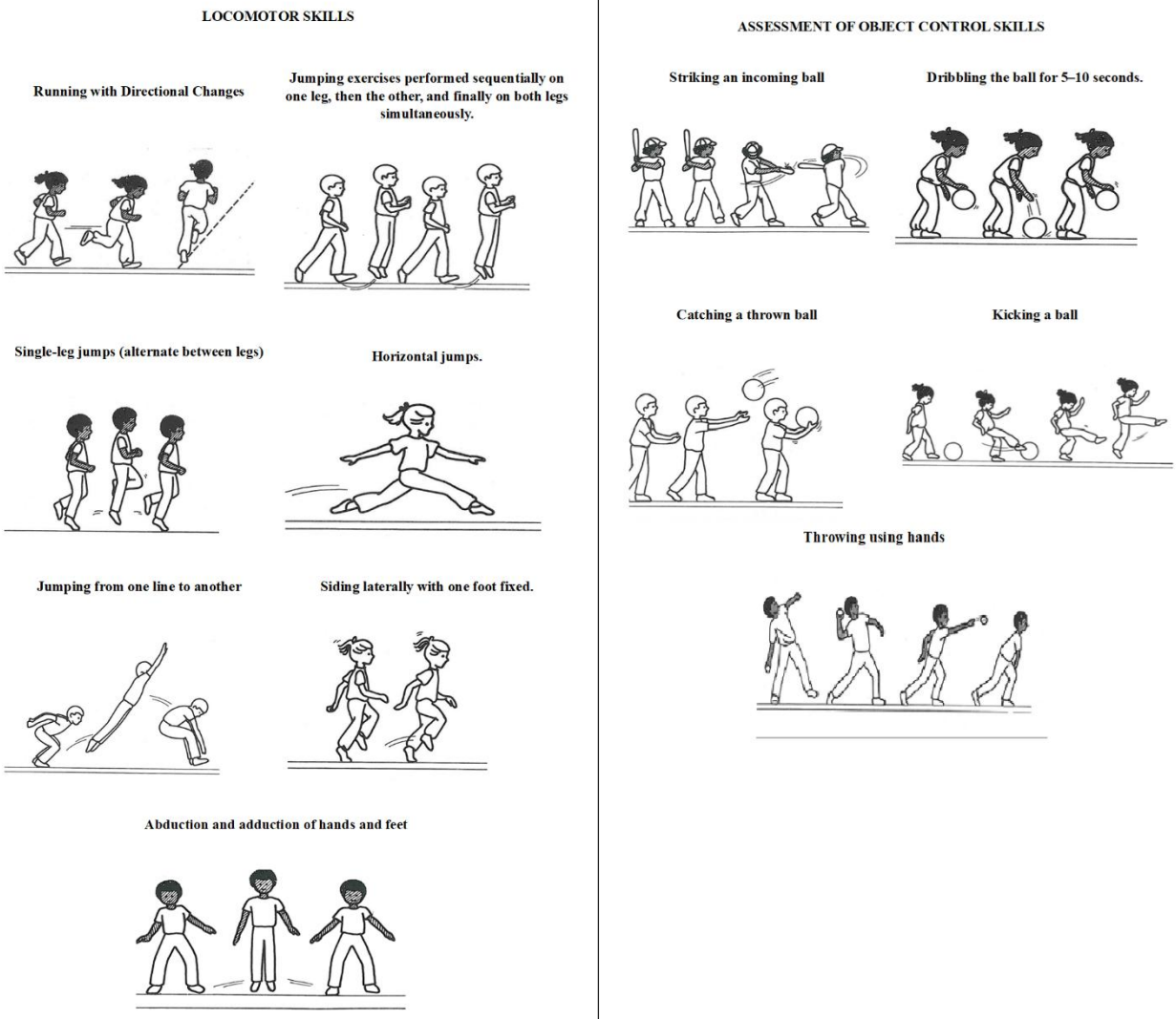

Figure 1. Test of Gross Motor Development (TGMD)

Notes: Adapted from publicly available TGMD-related educational resources [31]

Observational phase

In addition to parental reports, direct observation of each child's communication style, social gestures, responsiveness to verbal prompts, and emotional expression was conducted. This phase allowed the research team to refine individualized intervention plans and identify safety considerations.

Intervention program

Exercise selection

The rehabilitation program consisted of structured physical exercises targeting locomotor skills, balance, coordination, and strength. Activities included marching, knee lifts, crawling, floor scooting, jumping on one and two legs, abdominal exercises, treadmill walking, lateral walking, and running. Balance and coordination exercises incorporated the use of a balance board, ball catching while maintaining posture, hoop jumping, and walking along lined surfaces with controlled heel placement (Table 3).

Table 3. Physical exercises implemented during the program

Category	Exercise description
Ground and locomotion exercises	Standing on the ground and performing a military march (forward and backward)
	Standing on the ground and raising the knees (forward and backward)
	Crawling on the knees (forward and backward)
	Crawling on all fours (forward and backward)
	Floor scooting in a seated position
	Crawling movements (forward and backward)
	Jumping exercises (using both legs and one leg) forward and backward
	Squatting exercises
	Abdominal press exercises
	Walking exercises on a treadmill
	Walking forward and backward
	Running forward and backward
	Lateral walking (right and left)
Balance and coordination exercises	Standing on a balance board with both legs
	Standing on a balance board with one leg
	Catching a thrown ball with both hands while maintaining balance on the balance board
	Moving objects from right to left while seated on the balance board
	Jumping into and lifting up through hoops placed on the ground
	Walking across a lined surface by dropping the heels at designated points, followed by walking back with straightened feet

Test of Gross Motor Development (TGMD)

The Test of Gross Motor Development (TGMD), a widely validated instrument for children, was employed to assess locomotor (running, jumping, single-leg hops, lateral sliding) and object control skills (striking, dribbling, catching, kicking, and throwing). Each skill was demonstrated by the examiner, followed by three trials. Children received 1 point if the skill was performed correctly on at least two attempts. The maximum TGMD score was 12 (7 points for locomotor skills and 5 points for object control) [32].

Physical activity assessment

Physical activity levels were assessed using the Godin-Shephard Leisure-Time Exercise Questionnaire (GLTEQ), a validated self-report tool widely applied in pediatric and rehabilitation contexts. The GLTEQ records the frequency of strenuous (e.g. running, vigorous sports), moderate (e.g. fast walking, easy cycling), and light (e.g. easy walking, yoga) leisure-time physical activities performed for at least 15 minutes during a typical week [33]. Scores are calculated by multiplying the reported frequency of strenuous, moderate, and light activities by 9, 5, and 3 metabolic equivalents (METs), respectively, and summing the results. A Health Contribution Score (HCS) is further derived from the sum of moderate and strenuous components, representing activity levels most strongly associated with health benefits. Higher GLTEQ scores indicate greater weekly physical activity engagement.

Individualization of the program

Intervention sessions were structured to accommodate each child's endurance level and behavioral profile. Rest breaks were incorporated and gradually reduced to build stamina. Instructional materials and activities were adapted to individual preferences, cognitive level, and sensory sensitivities. Transition to new activities was gradual to minimize stress.

Data Analysis

All outcomes were analyzed descriptively, consistent with the methodological design of a case series. Pre- and post-intervention assessments were summarized descriptively to illustrate individual changes over time, rather than statistically compared. Motor skill scores, behavioral ratings, and physical activity indices were reported for each child to document patterns of change and clinically meaningful trends. No inferential statistics, hypothesis testing, or group-level comparisons were conducted. Observational notes and parent-reported indicators were integrated qualitatively to contextualize changes in motor performance, engagement, and adaptive behaviors across the intervention period.

Results

The 16-week physical rehabilitation program (four sessions per week) yielded measurable improvements in gross motor performance and reductions in autism-related behavioral manifestations among participating children aged 7-11 years. Baseline and post-intervention scores on the TGMD are shown in Table 4. All five participants demonstrated notable gains in locomotor skills, object control skills ("with subjects"), and overall TGMD totals.

Table 4. TGMD scores before and after the rehabilitation program

Participant	Locomotor before	Object control before	Total before	Locomotor after	Object control after	Total after
P1	3	2	5	5	4	9
P2	2	1	3	5	4	9
P3	3	2	5	6	4	10
P4	2	2	4	6	4	10
P5	4	3	7	7	4	11

A bar graph (Figure 2) illustrating total TGMD scores before and after the intervention clearly shows consistent improvement across all participants. Descriptively, total TGMD scores showed consistent increases across all cases, reflecting a general upward trend in motor skill acquisition.

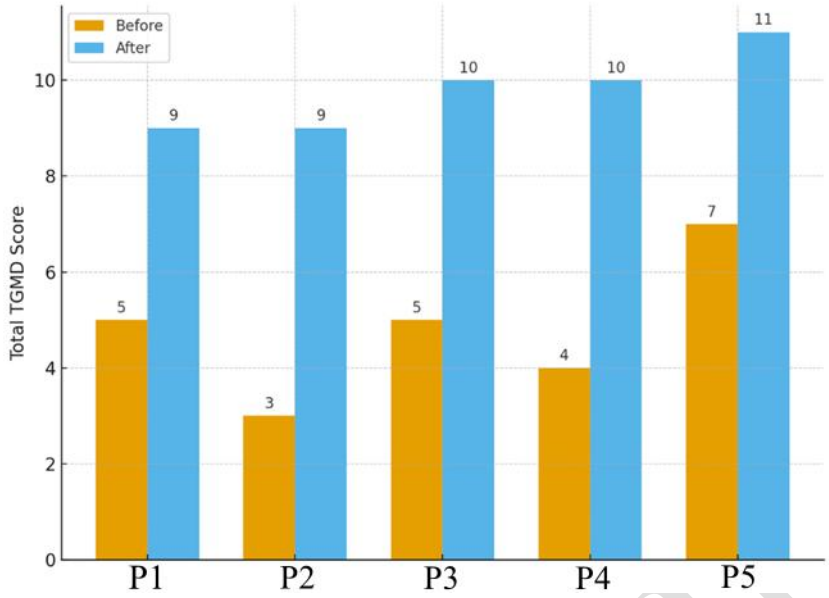

Figure 2. Total TGMD scores before and after the 16-week rehabilitation program (bar chart with "Before" vs. "After" for each participant)

In addition to motor outcomes, autism-related behaviors were assessed by a special education specialist at baseline and after 14 sessions, using two complementary rating scales (Tables 4 and 5). Scores on maladaptive manifestations (Table 5) declined in all children, with most shifting from "severe" or "moderate" categories at baseline toward "mild" or "low" levels post-intervention. Social-communication and adaptive skills (Table 5) improved markedly, with participants moving from low to moderate or high skill application categories.

Table 5. Change in autism-related maladaptive manifestations and social-communication/adaptive skills at the beginning and completion of the program

Domain/signs and skills	P1 1 lesson	P1 14 lessons	P2 1 lesson	P2 14 lessons	P3 1 lesson	P3 14 lessons	P4 1 lesson	P4 14 lessons	P5 1 lesson	P5 14 lessons
Autism-related maladaptive manifestations										
Poor eye contact	3	2	2	1	2	2	1	-	3	2
Ignores addressed speech	3	2	2	1	2	1	1	-	3	2
Fear of loud sounds	3	2	2	1	3	2	2	1	3	2
Social withdrawal	3	2	2	1	2	1	1	1	3	2
Lack of interest	3	2	2	1	2	1	1	-	3	2
Undesirable behavior	2	1	3	2	1	1	1	-	2	1
Negative response to touch	3	2	3	2	2	1	2	1	3	2
Anxiety in crowds	3	2	1	1	2	1	2	1	3	2

Stereotypic behavior	2	1	3	2	2	1	1	-	3	2
Hyperactivity	3	1	3	1	1	1	2	1	3	2
Mood swings	3	2	2	2	1	1	3	2	1	1
Total (Domain 1)	31	19	26	15	20	13	17	7	30	20
Social-communication and adaptive skills										
Perception of verbal instructions	1	2	2	3	2	3	3	3	1	2
Perception of gestures	1	2	2	3	2	3	2	3	1	2
Response to own name	2	3	2	3	2	3	3	3	1	2
Addressing others by name	1	2	2	3	1	2	3	3	1	2
Dressing independently	1	3	1	2	1	3	2	3	1	2
Verbal communication	1	2	2	3	1	2	3	3	2	3
Nonverbal communication	2	2	2	2	2	2	3	3	1	2
Use of social gestures	1	2	2	3	2	3	2	3	1	2
Balance and coordination	1	3	2	3	1	3	2	3	1	2
Physical endurance	1	3	2	3	1	3	1	3	1	2
Total (Domain 2)	12	19	24	28	15	27	24	30	11	20

Notes: The numbers "1" and "14" indicate the assessment time points corresponding to the first session (baseline) and the fourteenth session (mid-intervention), respectively.

Interpretation ranges

- Autism-Related Maladaptive Manifestations*:*
  11-17 = mild, 18-24 = moderate, 25-33 = severe
- Social-Communication and Adaptive Skills*:*
  10-16 = low, 17-23 = moderate, 24-30 = high

A composite line graph (Figure 3) comparing the total maladaptive score with the total adaptive skill score across time points highlights this dual trend: maladaptive manifestations declined, while adaptive skill acquisition rose steadily over the 16 weeks.

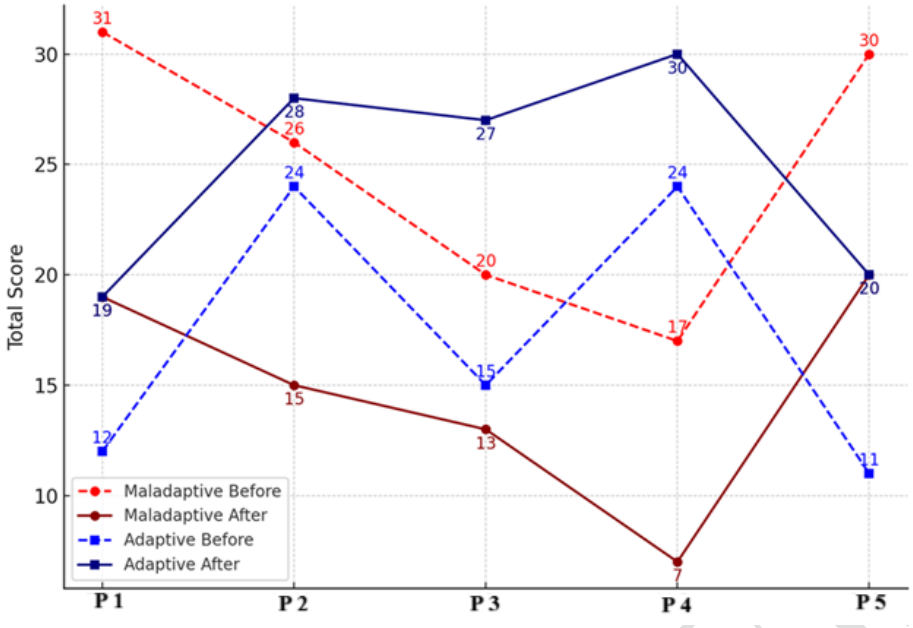

Figure 3. Descriptive changes in maladaptive behaviors and adaptive/social-communication skills before and after the intervention across the five participants (P1-P5)

Notes: The x-axis displays the five individual participants (P1-P5). The y-axis represents total scores for each behavioral domain. Two types of behavioral outcomes are plotted: maladaptive behaviors are shown with red lines, where higher scores indicate greater severity; adaptive and social-communication skills are shown with blue lines, where higher scores indicate better functioning.

Change in physical activity levels (GLTEQ)

Comparative GLTEQ scores before and after the 16-week rehabilitation program are presented in Table 6. At baseline, children demonstrated low-to-moderate levels of physical activity, with limited engagement in moderate-to-vigorous exercise. Following the intervention, all participants showed increased weekly activity scores, particularly in moderate and strenuous categories, reflecting improved functional capacity and greater participation in structured and spontaneous physical activities.

Table 6. Physical activity scores in study participants

Participant	GLTEQ total (Pre)	GLTEQ total (Post)	Health contribution score (Pre)	Health contribution score (Post)
P1	15	28	6	12
P2	12	25	5	11
P3	18	32	7	14
P4	10	22	4	10
P5	14	27	6	13

Notes: GLTEQ Total: total score from the Godin Leisure-Time Exercise Questionnaire; Health Contribution Score: weighted measure of moderate-to-vigorous activity contributing to health.

Overall, the data indicate that the individualized, evidence-based physical rehabilitation program substantially enhanced locomotor and gross motor development and produced concurrent improvements in social-communication behaviors and adaptive functioning in children with ASD. These descriptive findings align with previous research and underscore the potential value of individualized physical rehabilitation approaches for children with ASD.

Discussion

The present study aimed to develop and evaluate a structured physical rehabilitation program to enhance motor function and overall adaptive skills in children with ASD. The case descriptions illustrate that the 16-week individualized intervention was associated with observable improvements in motor performance and adaptive behaviors in these children. These findings underscore the critical role of targeted physical rehabilitation in addressing motor deficits and promoting functional development in children with ASD.

The improvement observed in gross motor skills, as measured by the TGMD, aligns with previous research demonstrating the effectiveness of structured motor programs in children with neurodevelopmental disorders. For instance, Rosales et al. reported that a 12-week motor skill intervention remarkably enhanced locomotor and object control skills in children with ASD, suggesting that focused, repetitive physical activities can promote both motor coordination and engagement in goal-directed movement [17]. Similarly, Bremer et al. emphasized that physical activity interventions contribute not only to motor skill development but also to improvements in behavioral regulation and social participation [11]. The current study corroborates these findings,

showing that children progressed from low-to-moderate baseline skill levels to high skill levels post-intervention, reflecting a meaningful functional gain over the program period.

The observed reduction in maladaptive behaviors, including stereotypic movements, social withdrawal, and sensitivity to auditory stimuli, further supports the use of physical rehabilitation as an adjunct to traditional educational and behavioral interventions. Consistent with prior literature, these outcomes suggest that structured physical activity may reduce anxiety, enhance attention, and promote adaptive behaviors in children with ASD [12]. Our study extends these observations by demonstrating that improvements in motor competence are accompanied by enhancements in social-communication abilities, including eye contact, responsiveness to verbal instructions, and the appropriate use of social gestures. These findings underscore the interrelated nature of motor, cognitive, and social development in this population and highlight the importance of an integrative, multidisciplinary approach.

The individualized nature of the intervention appears to have been particularly effective. Each child's program was tailored based on baseline assessments, including the severity of ASD manifestations, comorbid conditions, and specific motivational strategies identified by parents. Personalized interventions have been widely recognized as essential in pediatric rehabilitation, particularly for children with heterogeneous presentations such as ASD [34]. By accounting for each child's unique behavioral and physical profile, the program was able to maintain engagement, prevent fatigue, and optimize skill acquisition. The inclusion of parent-guided motivational strategies and reinforcement techniques likely contributed to the observed behavioral improvements, supporting previous evidence that family involvement enhances intervention efficacy [35].

Notably, the findings indicate that physical rehabilitation has broader benefits beyond motor skill development. Participants demonstrated improvements in self-care, independence in motor activities, and overall participation in structured sessions. To strengthen the evidence base and validate the observed patterns, larger-scale follow-up studies with more diverse participant groups are necessary. Such research would allow for more robust comparisons, clearer identification of intervention effects, and greater applicability to broader clinical and educational settings. While causal conclusions cannot be drawn from a case series, the observed changes coincided with the implementation of the individualized program [36]. This highlights the potential

of physical rehabilitation not only as a therapeutic modality but also as a tool for enhancing quality of life in children with ASD.

Despite these promising outcomes, several limitations should be considered. First, the small sample size (n=5) of the study limits the generalizability of the findings. While the results provide important insights into the potential efficacy of individualized physical rehabilitation, larger cohort studies are required to confirm these effects and evaluate their robustness across diverse populations. Second, the absence of a control group precludes definitive causal inferences regarding the intervention's effectiveness. Future research employing randomized controlled trial designs would strengthen the evidence base and allow for comparisons with alternative or standard-of-care approaches. Third, the relatively short intervention period (16 weeks) limits the assessment of long-term retention of motor and behavioral gains. Longitudinal follow-up is necessary to determine whether observed improvements are maintained over time and whether additional booster sessions are required to sustain skill development. Fourth, while the study incorporated observational and parent-reported measures, the potential for bias in reporting and assessment should be acknowledged. Objective measurement tools, such as motion capture technology or blinded evaluators, could enhance the precision of outcome assessments in future studies.

Moreover, the study focused primarily on gross motor development and did not systematically evaluate fine motor skills, sensory processing, or cognitive outcomes. These domains are often interrelated with motor function in children with ASD and may influence overall functional outcomes [24]. Expanding assessment protocols to include these domains would provide a more comprehensive understanding of intervention efficacy. Additionally, the study was conducted in a single rehabilitation center, and contextual factors such as staff expertise, facility resources, and family engagement may have contributed to the positive outcomes observed. Replication in diverse settings is necessary to evaluate the feasibility and adaptability of the program in different clinical and cultural contexts.

This study has important methodological limitations inherent to a case series design. The absence of a control group, small sample size, and lack of inferential statistical testing limit the ability to attribute observed changes directly to the intervention. All findings are descriptive and should be interpreted as preliminary patterns rather than evidence of effectiveness. The use of terms implying causality or statistical significance is not warranted in this design and has been

intentionally avoided to prevent overinterpretation. Larger, controlled studies are required to evaluate whether the observed improvements persist and can be replicated in broader populations.

Another limitation is the lack of age-group comparisons within the sample. Although all participants demonstrated observable improvements, the study design does not allow for examination of whether younger and older children may respond differently to individualized motor-based rehabilitation. Age-related differences in neuroplasticity, motor learning, attention, and behavioral regulation could meaningfully influence intervention outcomes. Future studies with larger samples stratified by age would enable clearer interpretation of developmental patterns and help determine whether specific program components should be adapted for different age groups.

Despite these limitations, the study contributes meaningfully to the literature on ASD rehabilitation by demonstrating the potential of structured, individualized physical rehabilitation to enhance motor and adaptive functioning. The results suggest that motor-based interventions can be effectively integrated into multidisciplinary rehabilitation programs, complementing pedagogical and behavioral strategies. The findings further emphasize the importance of individualized planning, parent involvement, and progressive skill challenges in maximizing the therapeutic benefits for children with ASD.

Conclusions

The present case series indicates that participation in an individualized physical rehabilitation program was associated with observable improvements in gross motor skills, adaptive behaviors, and social-communication abilities in children with ASD. These descriptive findings suggest that structured motor-based interventions may support functional development, although causal conclusions cannot be drawn due to the descriptive, uncontrolled nature of the study design. Future controlled studies with larger samples are needed to determine the efficacy and generalizability of these preliminary observations.

Disclosures and acknowledgements

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The authors declare that AI-based software (OpenAI ChatGPT, GPT-5, 2025 version) was used solely for initial language editing and formatting. The scientific content, interpretation, and references were entirely authored and verified by the undersigned authors.

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