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Group Physical Activity and Behavioral Practices in Adolescents with Autism: A Case Series on Integrated Educational Interventions

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Abstract

Research on physical activity (PA) interventions for individuals with autism spectrum disorder (ASD) has shown benefits in various domains, yet questions remain about how to implement such interventions in adolescents effectively. This study case-series study explores the contribution of a PA program integrated with applied behavior analysis (ABA) strategies in improving motor skills and reducing repetitive behaviors in three adolescents with ASD. The study used a pre-post case series design, with assessments at three time points (baseline, 6 months, and 9 months). The intervention consisted of 29 two-hour training sessions, held once a week in a public gymnasium. Standardized tools, including the Checklist for Autism Spectrum Disorder (CASD), the Social Responsiveness Scale (SRS-2), the Vineland Adaptive Behavior Scales (VABS), the Repetitive and Restricted Behavior Scale (RRBS), and the Movement Observation and Valuation for Individual Training (MOVIT), were utilized. Participants showed consistent improvements in all six motor skills evaluated by the MOVIT, with individual variations. The most significant gains were observed in intersegmental coordination, with acquisition rates increasing from 70% to 90%. Repetitive behaviors decreased, particularly restricted behaviors and modulation insufficiency, while changes in sensorimotor stereotypies were more modest. The preliminary results suggest that a PA program integrated with behavioral strategies is efficacious in improving motor skills and reducing repetitive behaviors in adolescents with ASD. These findings support the integration of physical activity into comprehensive educational interventions for this population.

Keywords: autism spectrum disorder; adolescents; physical activity interventions; applied behavior analysis; motor coordination; adaptive functioning; case series

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1. Introduction

The Research on physical activity (PA) interventions for individuals with autism spectrum disorder (ASD) has steadily increased over the past two decades. Lang et al. (2010)

emphasized that exercise programs incorporating adaptation, modeling, and active engagement are among the most effective and sustainable ways to promote PA in individuals with ASD. These interventions not only improve physical health but are also associated with reductions in maladaptive behaviors and increases in positive outcomes across various domains, including behavior, academics, and physical fitness (Suárez-Manzano et al., 2024). One of the most consistent findings is the reduction in stereotyped or self-stimulatory behaviors, often accompanied by decreases in aggression and self-injury. Additional benefits of PA include improvements in cognitive performance, particularly executive functioning, as well as gains in self-regulation (Sowa & Meulenbroek, 2012; Sorensen & Zarrett, 2014). A bibliometric analysis by Wang et al. (2022) highlighted the rapid expansion of research on PA interventions for ASD between 2003 and 2022, with a marked increase from 2014 onward, primarily driven by global research initiatives. This growing body of literature consistently demonstrates that PA not only improves physical health but is also associated with enhancements in mental well-being, reductions in maladaptive behaviors, and positive outcomes across behavioral, academic, and cognitive domains (Suárez-Manzano et al., 2024).

Among the most prolific contributors, Sean Healy has focused on increasing PA among youth with ASD and improving motor skills in developmental disabilities. Healy et al. (2018) reviewed 29 experimental studies, concluding that PA significantly enhances manipulative skills, locomotor abilities, fitness, social functioning, and muscular strength/endurance. Building on these findings, Reinders et al. (2019) reviewed 40 articles on PA and social functioning in ASD, revealing a bidirectional relationship: while social functioning modestly influences PA participation, PA has a more substantial impact on social skills, with contextual factors playing a critical role. Furthermore, meta-analyses have reinforced these results, showing that structured PA interventions can significantly improve social interaction and communication skills in children and adolescents with ASD, with interventions of at least 12 weeks being particularly effective (Huang et al., 2020).

Emerging evidence has further consolidated these findings. Rivera et al. (2025) conducted an integrative review synthesizing meta-analyses and clinical trials, reporting moderate to significant effects of PA on social communication and motor skills, and minor to moderate effects on stereotyped behaviors. Similarly, Xing and Wu (2025) confirmed that PA interventions reliably improve motor development in ASD, highlighting their relevance in both clinical and educational contexts. In parallel, comparative analyses have begun to examine specific exercise modalities. Kou et al. (2024) found that different types of physical activity (aerobic vs. skill-based) yielded varied benefits on social and behavioral outcomes, depending on the severity of ASD. Moreover, group-based PA interventions are receiving greater attention. Xing et al. (2025) demonstrated that structured group sports targeting fundamental movement skills can improve attention, imitation, cooperation, and social engagement in children with ASD. However, despite these benefits, barriers to participation persist. Salar et al. (2024) surveyed adolescents with ASD and their parents, identifying interpersonal challenges, lack of peer support, and organizational difficulties as significant obstacles, particularly during adolescence.

1.1. Physical Activity Interventions Increasing Motor and Cognitive Skills

Research has also addressed the cognitive and motor benefits of PA interventions. For example, Chan et al. (2015) investigated the effects of Nei Gong Training (NGT), a Chinese mind–body practice, in 66 children with ASD. Results indicated significant improvements in memory, particularly among children with lower intellectual functioning. Similarly, Travers et al. (2018) examined video-game-based balance training in adolescents with ASD, reporting preliminary improvements in postural control; however, the absence of control groups limited the generalizability. Other studies have investigated broader lifestyle interventions. Pan et al. (2021) analyzed PA and sedentary behaviors in Taiwanese youth with ASD, finding age-related differences in activity and inactivity patterns that underscored the importance of addressing sedentary lifestyles. Nabors et al. (2021) piloted a program integrating healthy eating and PA during the COVID-19 pandemic, with promising results in weight management and autonomy, though methodological limitations were noted. More recently, large-scale trials have provided more substantial evidence. Toscano et al. (2022) found that structured exercise training improved social and behavioral skills in 229 children and adolescents with ASD. These findings align with the integrative review by Rivera et al. (2025), which highlighted consistent effects of PA on both motor and cognitive outcomes. Xing et al. (2025) further confirmed improvements in motor development through structured PA, suggesting the importance of long-term, systematic approaches.

1.2. Physical Activity Interventions Targeting Challenging Behaviors

The reduction in motor stereotypies is critical because such behaviors can interfere with concentration, academic tasks, and daily routines. Early studies demonstrated that even brief sessions of PA can decrease stereotypy more effectively than passive activities such as television viewing (Watters & Watters, 1980). Rosenthal-Malek and Mitchell (1997) reported that exercise reduced stereotypic behaviors and improved academic performance in adolescents with ASD. Subsequent studies have further demonstrated that both the duration and intensity of exercise influence outcomes: while shorter sessions are effective in reducing stereotypies, more prolonged and vigorous exercise tends to produce longer-lasting effects (Levinson & Reid, 1993; Prupas & Reid, 2001). Educationally oriented programs, such as TEACCH, have also successfully integrated PA, utilizing structured environments, visual supports, and individualized activities to promote independence, reduce challenging behaviors, and generalize motor skills to peer interactions (Schultheis et al., 2000). More recent studies have suggested that PA may reduce stereotypies by serving as an alternative sensory-motor behavior. Neely et al. (2015) showed that antecedent exercise reduced stereotypy and increased academic engagement, while Tse et al. (2018) demonstrated that specific motor activities (e.g., ball-tapping exercises) could selectively reduce particular stereotyped behaviors such as hand-flapping. Recent evidence reinforces these findings in educational contexts. Kou et al. (2024) reported that different physical activity modalities variably reduce stereotypies, with aerobic activities often producing the most potent effects. Xing et al. (2025) highlighted that group-based motor activities can simultaneously decrease repetitive behaviors and enhance cooperative play. Salar et al. (2024) emphasized that addressing barriers such as limited social support and inadequate structured supervision is essential for sustaining reductions in challenging behaviors.

1.3. The Present Study

Taken together, the literature suggests that physical activity can provide important benefits across motor, cognitive, behavioral, and social domains for individuals with ASD. However, questions remain regarding how these interventions can be most effectively implemented during adolescence, a developmental stage in which barriers to participation often intensify and educational outcomes become increasingly significant (Srinivasan et al., 2014). In particular, there is a need to clarify whether group-based PA interventions can significantly enhance motor competencies, whether participation in structured PA can reduce motor stereotypies and other repetitive behaviors, and to what extent baseline characteristics—such as adaptive functioning, repetitive behaviors, and cognitive performance—moderate the effectiveness of these programs. Addressing these questions can provide valuable insights into how PA may be integrated into comprehensive educational interventions for adolescents with ASD.

2. Materials and Methods

2.1. Participants and Setting

The present study was conducted in a public gym located in Italy. Participants were three male adolescents, aged 17–18 years, all of whom were enrolled in a community-based rehabilitation center. Each adolescent regularly participated in structured educational and social activities, including theater workshops, counseling sessions, and autonomy training based on applied behavior analysis (ABA). Prior to enrollment, all participants, together with their families, provided informed consent to participate in the group-based PA program.

Manuel lived with his mother, her partner, and his brother, and attended a local high school, maintaining regular attendance, which alternated between in-person and distance learning due to COVID-19 regulations. At baseline, he was engaged in weekly psychological counseling and a social skills group organized by the public health service. No medical conditions (e.g., allergies, pharmacological treatments) were reported. His mother reported a history of dyslexia and stuttering exacerbated by anxiety, although his expressive language and vocabulary were age appropriate. He demonstrated adequate gross motor abilities and well-developed fine motor skills. In terms of autonomy, he was independent in personal care and could prepare simple meals; however, he required occasional support with managing his finances. His interests included video games, woodworking, and creative decoration. He expressed strong motivation to engage in group PA, particularly boxing and strength training.

Dean lived with his parents and sister and also attended high school under a blended learning model. No medical conditions were reported, though his parents noted a severe fear of water, for which he had not received prior intervention. His expressive language was age-appropriate but limited; he spoke softly, provided short responses, and rarely initiated interactions. While receptive language was intact, he showed avoidance behaviors and social withdrawal in peer contexts. Motor evaluation revealed postural difficulties and an unsteady gait inconsistent with age expectations. He was autonomous in self-care and enjoyed reading, drawing, and watching documentaries. Although initially reluctant, he developed motivation to participate during the gym sessions.

Gene lived with his mother and sister and attended a science-oriented high school, where he also participated in a public health service socialization group. His mother reported psychological difficulties related to adjustment following his autism diagnosis, which had been communicated two years earlier. Gene displayed good linguistic skills and was able to sustain conversations, particularly about preferred topics, but struggled with irony, non-literal language, and symbolic communication. He expressed a preference for in-person schooling due to opportunities for peer interaction but showed difficulties with reciprocity in social relationships. He was autonomous in personal care and several community tasks (e.g., scheduling appointments), though he required support with decision-making. His main leisure interests included video games and board games. While his fine motor skills were intact, he experienced challenges with advanced coordination tasks. Motivated to improve his health and physical appearance, Gene began a diet concurrent with the training program.

2.2. Research Design

This study employed a pre–post case series design with repeated assessments at three time points (baseline, 6 months, and 9 months). Such designs are commonly adopted in applied educational and clinical research when small samples preclude the use of randomized trials, with a focus on individual trajectories (Kazdin, 2021). This design was selected as it is particularly suited to preliminary investigations in real-world settings where full experimental control is not feasible, yet detailed monitoring of change is critical.

The research team consisted of the interventionists (a personal trainer, a behavioral technician, and a behavioral analyst) and an external research assistant who was not involved in the intervention delivery. This assistant conducted the parent interviews and was responsible for data collection to minimize bias. The structured interview collected information on diagnostic history, symptom severity, and concurrent interventions, including their frequency and duration. Standardized assessments, interviews, and questionnaires were administered to establish baseline functioning and contextual variables. All participants and their caregivers provided written informed consent to participate in the study and to allow dissemination of data. Ethical approval was obtained from the private provider (Protocol ID: COMUNITABA-01062022, date of approval: June 2021), who supported the mere realization of the training. The program itself was delivered as part of routine educational and clinical practice; therefore, no additional risk was introduced for the participants. Documentation of consent and study procedures is available for review upon request.

2.3. Instruments

The Checklist for Autism Spectrum Disorder (CASD) is a standardized diagnostic instrument developed by Mayes to assist clinicians in identifying ASD across a broad developmental range (Mayes, 2018). The tool includes 30 core symptoms that reflect behaviors and developmental features consistently associated, regardless of cognitive level, language ability, or age. These symptoms are organized into six domains: social interaction, communication, perseverative and stereotyped behaviors, sensory sensitivities, attention and safety, and motor and adaptive behaviors. The CASD can be administered via a semi-structured caregiver interview, direct observation, and developmental history review. A score of 15 or higher is considered indicative of ASD, offering both a quantitative threshold and a qualitative profile of symptom distribution. The CASD is valued for its brevity, clinical utility, and robust psychometric properties. Validation studies demonstrate high sensitivity and specificity in distinguishing children with ASD from those with other developmental or psychiatric conditions, supporting its use as both a diagnostic adjunct and a screening measure in clinical and research contexts (Tierney et al., 2015).

The Social Responsiveness Scale, Second Edition (SRS-2) was validated by Bölte et al. (2008) across different cultures and applied in Italy (Paolizzi et al., 2025). It is a 65-item questionnaire designed to quantify social impairment associated with ASD. It provides scores across five subscales: Social Awareness, Social Cognition, Social Communication, Social Motivation, and Restricted Interests and Repetitive Behavior (Mannerisms). Items are rated on a 4-point Likert scale (1 = not true, 4 = almost always true), with higher scores indicating greater impairment. In the present study, caregivers completed the SRS-2 to provide an additional standardized measure of social functioning, complementing observational and adaptive behavior assessments.

The Vineland Adaptive Behavior Scales-Second Edition (VABS-2; Italian implementation by Valenti et al., 2022) assesses adaptive behavior, defined as personal and social sufficiency in everyday life, and measures how cognitive abilities translate into functional autonomy. Administered through a semi-structured caregiver interview, the VABS evaluates four domains: Communication (receptive, expressive, and written), Socialization (interpersonal relationships, play and leisure, and coping), Daily Living Skills (personal care, domestic tasks, and community use), and Motor Skills (gross and fine motor). Items are rated on a three-point scale (2 = performed independently, 1 = performed sometimes/partially, 0 = never performed). Items are developmentally calibrated, enabling valid comparisons across age groups.

The Repetitive and Restricted Behavior Scale (RRBS) measures the frequency and severity of restricted, repetitive, and stereotyped behaviors in individuals with neurodevelopmental conditions (Bourreau et al., 2009). It includes 35 items rated on a five-point Likert scale (0 = never observed, 4 = highly characteristic/frequent), grouped into four macro-domains: sensory–motor stereotypies, resistance to change, restricted behaviors, and insufficient modulation. The questionnaire yields a total severity score and has been widely applied in both clinical and research contexts to quantify behavioral rigidity and monitor the outcomes of interventions.

Motor skills were assessed using the Movement Observation and Valuation for Individual Training (MOVIT; Palumbo et al., 2021), a standardized tool designed to evaluate psychomotor development in educational and rehabilitative contexts. The entire instrument comprises 36 sub-capacities, articulated across 180 individual tasks, covering domains such as balance, coordination, spatial–temporal structuring, graphomotor skills, and functional autonomy. For this study, six capacities and 30 related sub-capacities were retained for analysis. Conversely, graphomotor and fine motor skills (e.g., copying simple figures, paper folding, pencil grasp, bimanual coordination) were not included as targets in the present intervention, as they did not represent the primary focus of the educational and therapeutic program. The six functional capacities and their sub-capacities are each operationalized through concrete, observable tasks. Within this framework, the first capacity (1), Tone and Relaxing, examines the regulation of motor tone and inhibitory control by asking participants to alternate activity and rest on a salient cue, to accept passive movements or oscillations of the limbs without resistance, and to perceive the progressive normalization of breathing and heart rate after exertion, including the ability to report localized changes in muscle tension. The second capacity (2), Balance and General Dynamic Coordination, assesses both static and dynamic postural control through tasks such as quiet standing with feet together or in tandem, tiptoe stance with and without ball handling, single-leg balance with eyes open or closed, walking and running on straight or curved lanes of defined width, negotiating low obstacles, climbing steps, skipping, and performing controlled jumps and hops without loss of equilibrium. The third capacity (3) focuses on Segmental and Intersegmental Coordination and progresses from isolated limb actions to multi-segment combinations. Participants complete flexion–extension, arm circles, and sagittal swings, then advance to symmetric and alternating patterns that integrate arms and legs, and to arm–head coupling where head rotation must be synchronized with or counterposed to upper-limb motion; more complex items require open–close jumps with coordinated arm raises or knee bends. The fourth capacity (4) targets Hand and Oculo-manual Coordination and Graphomotor Skills and includes bimanual manipulation (crumpling and folding paper, opening wrappers), establishment of a tripod grasp and controlled tracing of lines, shapes, and letters, functional handiwork such as cutting along a circle, buttoning and tying shoelaces, and precision striking of balls or targets from different positions; fine-motor timing and sequencing are further challenged by rapid, patterned finger-tapping exercises. Spatial Orientation constitutes the fifth capacity (5). It evaluates the mastery of topological concepts and proper–left orientation on oneself and on others, the ability to adapt movement in relation to peers within constrained spaces without collisions, the appreciation of metric relations such as distance and density during locomotion, and spatial memory through the repetition and graphic reproduction of obstacle courses, the reconstruction of team positions after a brief rally, and the reproduction or retracing of an unfamiliar path. The sixth capacity (6), Temporal Structuring, captures the perception and organization of time in movement. Participants are asked to synchronize actions with a regular beat, to insert and respect pauses within ongoing sequences, to accentuate specific phases of a movement on the strong beat, to discriminate fast from slow tempi and adapt previously learned sequences to a changed pace, to appreciate and reproduce movement duration, and to perceive and replicate rhythmic structures by scanning the rhythm of sequences performed by a peer or the educator. Across all capacities, tasks are specified with objective parameters—durations in seconds, distances in meters, lane widths in centimeters, and target sizes—to ensure replicability and to facilitate comparison across sessions. Scoring is criterion-referenced and uses a three-level rubric that distinguishes between correct performance without errors (score 2), partially correct execution or performance requiring minor assistance or standardized adaptations (score 1), and failure or non-performance (score 0).

2.4. Procedure and Intervention Protocol

The training program was conducted in a public gym and consisted of 29 sessions, held once per week for two hours, from June 2021. Each session was delivered by a personal trainer and a behavioral technician, with supervision every fifteen days by a Board Certified Behavior Analyst (BCBA). The intervention combined group-based and individualized exercises. Before each exercise, a stimulus preference assessment was conducted to identify reinforcing activities to be delivered at the end of the task. This approach aligns with ABA best practices, aiming to individualize motivation (Hagopian et al., 2004). Recent evidence suggests that including preferred stimuli can enhance engagement and decrease problem behaviors (Leif et al., 2020). Selected reinforcers included listening to music, performing advanced exercises, or taking five-minute breaks. Behavioral strategies were systematically embedded. Clear instructions, consistent with antecedent-based interventions, were provided before tasks (Wood et al., 2018). Modeling was used to demonstrate correct movements, a method supported by observational learning principles in ASD (Foti et al., 2014). Feedback on performance and peer collaboration was provided immediately, as research has shown that immediate positive feedback enhances skill acquisition (Livingston et al., 2025). Social praise served as a positive reinforcer, consistent with its established role in reinforcing adaptive and social behaviors, as well as the implementation of a token economy system (Bassette et al., 2018). When dysfunctional behaviors occurred (e.g., escape, avoidance, verbal or physical aggression), the rules were re-explained, and collaboration with the participant was used to support cooperation via antecedent-based support strategies (Wong et al., 2023). In rare cases of severe behavior (e.g., screaming, throwing objects), a time-out from activity was applied. At the same time, modern guidelines favor less intrusive alternatives; timeout remains a secondary measure when necessary and ethically implemented (Ferris et al., 2025). Attendance was tracked. Manuel and Gene each missed seven sessions, while Dean missed ten. To address absenteeism, participants were taught to report expected absences at least one day in advance. A differential reinforcement of alternative behavior (DRA) procedure was used: participants reporting absence appropriately received double reinforcement time. Systematic reviews conducted in 2024 confirm the efficacy of DRA in applied settings for reducing challenging behaviors and promoting compliance (Muharib & Walker, 2024). To ensure the internal validity of the study, the procedural fidelity of the intervention was assessed. An independent observer, trained on the intervention protocol but not involved in its delivery, evaluated a randomly selected sample of 9 sessions (approximately 30% of the total) using a priori-developed checklist. The checklist, available in Appendix B (Tables A2 and A3), comprised 15 items designed to measure adherence to the key structural, procedural, and behavioral components of the intervention as described in the protocol. Each item was scored using a 3-point scale (Yes = 1 point; Partially = 0.5 points; No = 0 points). The fidelity for each session was calculated as a percentage of the total points earned relative to the maximum possible score. The results indicated a high level of adherence, with a mean fidelity score of 92.2% (range, 80.0–100%) across all observed sessions. This level of fidelity exceeds the 80% threshold commonly accepted as robust in intervention research, supporting the conclusion that the observed outcomes are attributable to the intervention as it was designed (Ledford & Wolery, 2013).

The intervention was tailored to each adolescent's developmental profile while building on shared educational objectives and core physical activity (PA) tasks. Training activities were cataloged and tracked in a comparative matrix that aligns each exercise with its Domain/Capacity, Sub-Capacity, and the specific Training Task description (including parameters such as duration in seconds, distance in meters, and target dimensions where applicable). For every task row, three participant columns (Manuel, Dean, Gene) indicate assignment using a checkmark (✓); blank cells denote tasks not implemented for that participant. The complete matrix is provided in Appendix A (Table A1: Comparative Training Task Matrix). Organization by motor domain. Tasks were grouped under the same domains used in the individual plans: (1) Tone and Relaxing; (2) Balance and General Dynamic Coordination; (3) Segmental Coordination; (4) Intersegmental Coordination; and (5) Spatial Orientation. Within each domain, exercises were further specified by Sub-Capacity (e.g., Balance on tiptoes, Balance on one foot, Symmetrical/Asymmetrical arm–leg movements, Right–left on self/others, Movement in relation to peers, Spatial localization of objects, Spatial memory, etc.). This structure clarifies the functional target of each activity, allowing for direct mapping between individual goals and the implemented practice.

Group (shared) tasks. Several exercises were deliberately designed and scheduled as group tasks, i.e., tasks implemented for more than one participant (and often for all three), to promote consistency of exposure and opportunities for cooperative practice. Shared group items included: Balance on tiptoes (e.g., stand on tiptoes, hands on hips, 10″; balance on tiptoes, eyes open, while catching/throwing a ball from 2 m, 10″). Balance on one foot (eyes closed variants on dominant and non-dominant sides). Runs/hops/jumps on the spot (e.g., skipping 20″; jumps on the spot on dominant and non-dominant leg, 15″; knees-to-chest jumps, 15″). Tone and Relaxing transition drills (e.g., arm circles with direction inversion on verbal command). Intersegmental/segmental coordination samplers (e.g., bicycle exercise; forward–backward arm swings; side jumps with frontal-plane arm raises). Spatial orientation with others (e.g., indicating right/left hand, foot, eye, ear on a peer; running and passing peers on verbal request, same/opposite facing direction). Spatial localization of objects (e.g., accuracy throws at 60 cm and 30 cm targets from 5 m; throws to a moving educator along the short side of the gym). In the matrix (Appendix A), these rows show ✓ in multiple participant columns, reflecting their group delivery.

Individualized (participant-specific) tasks. In parallel, the matrix documents individual assignments that targeted participants' specific profiles within the same domain framework: Manuel completed an expanded set in Spatial Orientation → Spatial memory, including reproduction of obstacle courses on paper, graphical reproduction of players' positions after a short ball-passing/volleyball sequence, and navigation of unfamiliar city paths (≈100 m; 2 right + 2 left turns) with return to start and/or graphical reproduction. These tasks are listed under Spatial memory, with ✓ only in Manuel's column. Dean received a denser progression under Balance and General Dynamic Coordination, focusing on running with balance/jumps with balance, emphasizing curvilinear running within narrow lanes (20–30 cm) with low obstacles (10–20 cm) and single-leg hopping along straight and curved paths (8 m) within a 40 cm lane. These rows carry a ✓ in Dean's column and are blank for others when not assigned. Gene had a stronger focus on Segmental Coordination (e.g., arm–head coupled movements, opening one arm at a time while tracking with head rotation, leg swings with same-side/opposite-side hand touches) and combined patterns such as arm swings with knee bends. Corresponding rows show a ✓ in Gene's column, distinguishing his individualized emphasis. Standardized task parameters and comparability. Where feasible, dosage and constraints were held constant across participants for the same task (e.g., 10″ tiptoe holds, 15″ jump sets, 5 m throw distance, 8 m single-leg hop paths) to facilitate comparability while preserving safety and feasibility. Variants (e.g., lane width, presence of obstacles, curved vs. straight path) are specified directly in the Training Task field of each row, enabling fine-grained interpretation of task difficulty and context. The mastery criteria for each item included correctly performing the task three times, with 100% accuracy. Maintenance tasks were provided at all times in rotation. After the training, we leave time for group ball games or to visit the gym, where we can play volleyball, run on the field, and participate in other activities that they find enjoyable. Clearly, the first domain (1) was submitted less frequently due to its simplicity, in contrast to the last (6), which was mostly difficult to perform. Many of the exercises were collected to control the indirect progress.

2.5. Data Analysis

Baseline symptomatic, adaptive, and social–behavioral profiles were summarized using descriptive statistics (means and standard deviations) derived from standardized instruments. For motor outcomes, performance was assessed at three time points (T0 = baseline, T1 = 6 months, T2 = 9 months) across hierarchical domains of motor functioning, each decomposed into sub-capacities operationalized by multiple tasks. Each task was scored on a three-level ordinal scale (0 = not performed, 1 = partially performed, 2 = correctly performed). For each sub-capacity and participant, the primary descriptive outcome was the mean proportion of correct executions (score = 2) relative to all administered tasks. Non-administered items were treated as missing and excluded from denominators. Given the small sample size and the ordinal nature of the data, analyses prioritized non-parametric effect size estimation rather than significance testing. Specifically, we computed the Tau-U statistic (Parker et al., 2011), which quantifies non-overlap between phases while controlling for baseline trends, and provides an interpretable effect size ranging from −1.00 (systematic deterioration) to +1.00 (systematic improvement). Exact confidence intervals (95%) were estimated using distribution-based methods. Longitudinal changes were illustrated descriptively through line graphs and percentage changes at the sub-capacity level. Effect sizes (Tau-U) were reported separately for each participant and sub-capacity, and then summarized to highlight convergent trends. Given the exploratory and pilot nature of the study, *p*-values were not interpreted as confirmatory evidence, but only as complements to effect sizes when relevant. No corrections for multiple testing were applied. To explore the potential role of baseline characteristics as moderators of intervention outcomes, a formal statistical analysis (e.g., correlation) was not appropriate given the small sample size (n = 3). Instead, we employed a descriptive, case-by-case pattern-matching approach (Almutairi et al., 2014). For each potential moderator (i.e., baseline scores from the RRBS, VABS, CASD, and SRS-2), we first formulated clinically informed hypotheses. We then tabulated these baseline scores for each participant alongside their primary motor outcomes—defined as both the mean improvement (Δ% = T2% − T0%) and the variability of improvement (standard deviation of Δ% scores across the six MOVIT capacities). Finally, these tabulated data were visually inspected to identify patterns that either supported or contradicted our initial hypotheses. This approach is designed to be exploratory and hypothesis-generating, laying the groundwork for future research with larger sample sizes.

3. Results

Baseline assessments (T0), summarized in Table 1, revealed heterogeneous clinical profiles among the three participants, highlighting significant differences that extend beyond general symptom severity. In terms of overall autism symptomatology (CASD), Dean presented with the highest score (20), indicative of a more severe presentation, followed by Gene (18) and Manuel (15), whose scores were at the clinical cutoff. This trend was partially reflected in the Social Responsiveness Scale (SRS-2) scores, where Dean showed the most significant impairment across several areas. However, a deeper analysis of the subscales revealed crucial, non-linear differences. The most striking divergence emerged in Social Motivation (SRS-2): Manuel presented with a T-score of 35, well within the typical range, indicating a strong intrinsic drive for social engagement. In contrast, both Dean (T = 68) and Gene (T = 64) exhibited significant deficits in this area. Socialization skills (VABS) also showed a heterogeneous pattern: Gene had the strongest profile (age equivalent of 16 years), followed by Manuel (12 years), while Dean showed a very significant delay (6 years). The profiles of restricted and repetitive behaviors (RRBS) were also unique to each participant. Manuel showed the highest scores in Reaction to Change and Restricted Behaviors, suggesting a profile characterized by greater rigidity. In contrast, Gene presented with the most difficulty in Modulation Insufficiency. Surprisingly, Dean showed very low scores in Reaction to Change and Modulation Insufficiency, indicating these were not primary areas of concern for him at baseline. Finally, in daily living skills (VABS Daily Living), Manuel and Gene had similar and higher abilities (age equivalent of 15 years) compared to Dean (10 years). Overall, these baseline data reveal three distinct profiles: Manuel, characterized by high rigidity but strong social motivation; Dean, exhibiting the greatest symptom severity and social deficits, yet less rigidity; and Gene, displaying good social skills but significant modulation difficulties. These individual differences provide the essential context for interpreting the change trajectories observed during the intervention.

Table 1. Baseline assessments.

	Age	CASD	Social Responsiveness Scales				Vineland			Repetitive and Restricted Behavior			
Subjects	**Year**	**Severity**	**Awareness**	**Cognition**	**Communication**	**Motivation**	**Communication**	**Daily Living**	**Socialization**	**Sensory Motor**	**Reaction to Change**	**Restricted Behaviors**	**Modulation Insufficiency**
Manuel	18	15	74	73	79	35	13 *	15 *	12 *	9	13	15	13
Dean	17	20	77	72	90	68	11 *	10 *	6 *	10	4	7	3
Gene	17	18	65	71	79	64	12 *	15 *	16 *	9	10	9	17

* VABS are age equivalents.

3.1. Capacity-Level Outcomes

Visual inspection of Figure 1 reveals consistent improvements across all six MOVIT capacities, although the magnitude of these improvements varied. Tone and Relaxing (Capacity 1): Participants demonstrated modest but reliable progress in shifting from activity to inactivity. Average improvements were +10–15 percentage points, with Tau-U values in the small range (0.30–0.40). Balance and General Dynamic Coordination (Capacity 2): Both static and dynamic balance improved moderately, with increases of +20–40 percentage points. Tau-U values ranged from 0.45 to 0.55, indicating small to moderate effects. Segmental Coordination (Capacity 3): Substantial gains were observed in symmetrical and asymmetrical limb coordination. Mean improvements were +40–60 percentage points, with Tau-U values between 0.60 and 0.75, indicating moderate-to-large effects. Intersegmental Coordination (Capacity 4): This capacity showed the strongest overall growth, particularly in combined arm–leg–head movements. Acquisition rates increased by +70–90 percentage points, with Tau-U consistently between 0.70 and 0.85 (significant effects). Spatial Orientation (Capacity 5): Participants improved in right–left discrimination, spatial localization, and simplified spatial memory tasks. Gains were +25–50 percentage points, supported by Tau-U values of 0.55–0.70. Temporal Structuring (Capacity 6): Progress was moderate across rhythm reproduction and duration tasks, with mean increases of +20–30 percentage points. Tau-U values ranged from 0.50 to 0.60, suggesting modest but consistent effects.

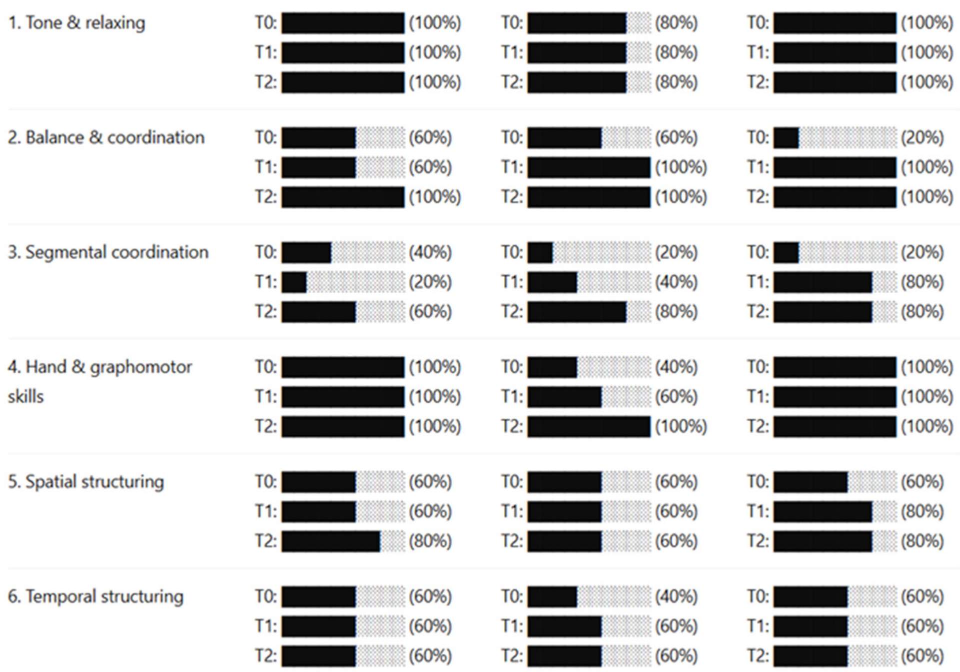

Figure 1. Developmental outcomes across motor capacities at baseline, midline, and post-test. Note. Percentages represent the complete acquisition of tasks scored "2" on the MOVIT, corresponding to the Manuel, Dean, and Gene scores in the columns. Bars in the original figure indicate relative levels of acquisition at each time point (darker/longer = higher acquisition).

3.2. Sub-Capacity Outcomes

A more detailed analysis of the 30 sub-capacities highlighted differential responsiveness to the program. Balance on one foot improved by +25–40 percentage points (Tau-U = 0.50–0.55), while balance on both feet reached the ceiling earlier. Asymmetrical arm–leg coordination increased from near-zero to greater than 80% correct execution (+80 pp; Tau-U = 0.75). Full-body coordination, including head movements, showed the steepest trajectory (+90 pp; Tau-U = 0.80–0.85). Spatial localization of objects improved by +30–45 pp, Tau-U ≈ 0.60, whereas simplified spatial memory tasks showed more gradual but still positive change. Temporal structuring sub-capacities progressed heterogeneously: reproducing a simple rhythm and adapting to regular rhythm improved moderately (+20 pp; Tau-U ≈ 0.50), while differentiating durations and reproducing movement length showed smaller but steady gains.

3.3. Individual Trajectories

Individual-level trajectories confirmed that gains were present across participants, but with differences in pace and magnitude. Manuel reached ceiling levels in fine motor and graphomotor tasks early in the program but exhibited the strongest growth in imitation and intersegmental coordination (Tau-U > 0.70). Dean displayed balanced improvements across capacities, with substantial effects in combined limb and full-body coordination (Tau-U = 0.75). Gene progressed more gradually overall, but showed reliable gains in imitation, asymmetrical coordination, and spatial orientation tasks (Tau-U = 0.62).

3.4. Changes in Repetitive Behaviors from Baseline to Post-Intervention

Analysis of the Repetitive and Restricted Behavior Scale (RRBS) from baseline (T0) to post-intervention (T2) revealed a pattern of selective improvement across its four domains, as illustrated in Figure 2. The most pronounced changes were observed in the domains of Restricted Behaviors and Modulation Insufficiency. In both areas, all three adolescents displayed parallel and consistent reductions in scores at T2. The clear downward trend suggests clinically meaningful improvements in these specific behavioral patterns, aligning with prior findings that structured programs can effectively reduce behavioral restriction and enhance regulatory capacities. In contrast, changes in Sensory-motor Stereotypies were more modest. While a slight decline was noted across participants, the reduction was most evident for Manuel, with Dean and Gene showing only minor changes. This suggests a more limited, though still positive, impact of the intervention on this type of behavior. Finally, the domain of Reaction to Change remained largely stable throughout the intervention period for all three participants. The minimal variation in these scores suggests that the program did not have a significant impact on this specific aspect of behavioral rigidity. Taken together, these results underscore a pattern of differential responsiveness. The intervention appeared to be most effective in reducing restricted patterns of behavior and improving regulatory capacities, while having a more limited effect on sensory-motor stereotypies and behavioral inflexibility. This finding provides preliminary support for the targeted benefits of an integrated physical activity program on specific forms of repetitive behavior in adolescents with ASD.

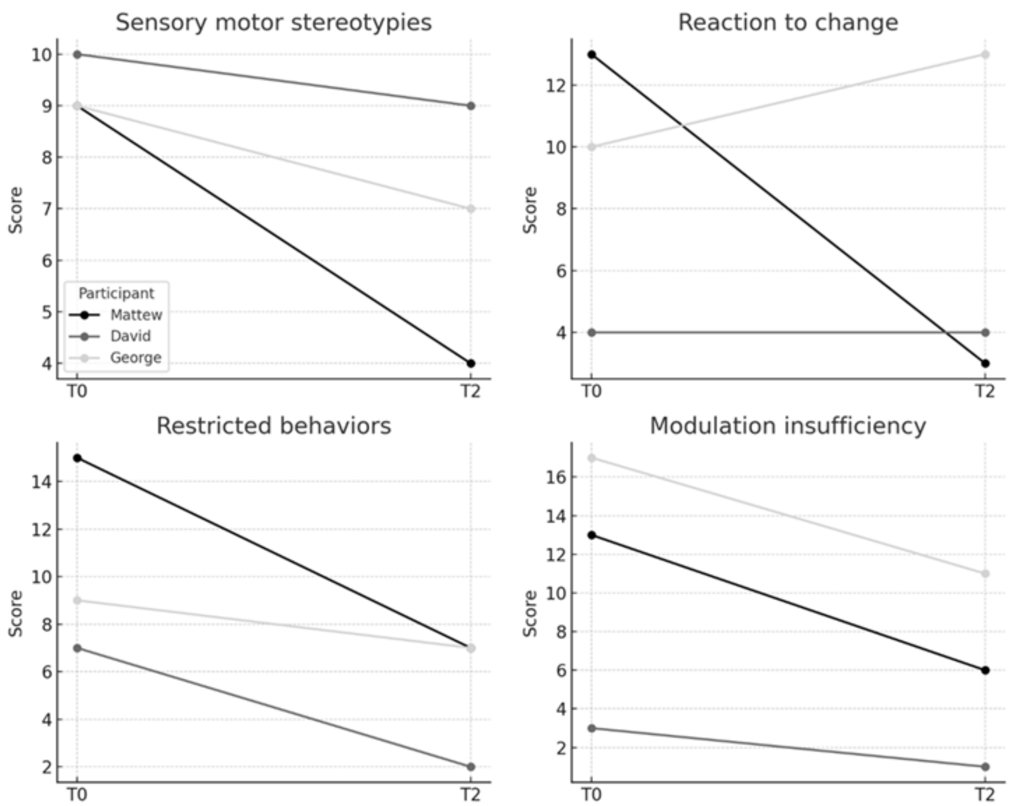

Figure 2. Individual trajectories of RRBS domains from baseline (T0) to post-intervention (T2). Each line represents one participant. Improvements are particularly evident in restricted behaviors and modulation insufficiency, whereas reaction to change remained broadly stable.

3.5. Exploratory Analysis of Baseline Characteristics as Potential Moderator

A descriptive, case-by-case analysis was conducted to explore how baseline behavioral and adaptive profiles may have influenced intervention outcomes (see Table 2). To facilitate this, we quantified motor outcomes by calculating the mean improvement (Mean Δ%) and the variability of that improvement (SD of Δ%) across the core motor domains of Balance and Coordination. The results are presented alongside key baseline moderator scores in Table 2. Repetitive Behaviors (RRBS) and Consistency of Gains: the data suggest a strong relationship between lower behavioral rigidity and more consistent, robust motor progress. As shown in Table 2, Dean, who had the lowest score on the Reaction to Change subscale, achieved both the highest mean motor improvement (48.0%) and the most consistent gains (SD of Δ% = 7.1%). Conversely, Gene and Manuel, who presented with moderate to high rigidity scores, showed more variable progress (SD of Δ% > 16%). This pattern supports the hypothesis that behavioral rigidity may act as a significant barrier, not necessarily to teaching itself, but to the uniform and efficient acquisition of new motor skills. A Nuanced Look at Social Functioning (SRS-2 and VABS) as a Moderator: The role of social functioning appears to be more complex. A compelling pattern emerged from the Social Motivation (SRS-2) subscale. Manuel, the only participant with typical motivation (T-score = 35), achieved substantial motor gains (36.5%) despite his high behavioral rigidity. This suggests that high intrinsic social motivation may act as a protective or compensatory factor, helping individuals overcome barriers such as rigidity. On the other hand, pre-existing Socialization skills (VABS) did not directly predict the magnitude of improvement. Gene, with the strongest socialization skills, showed the most modest gains. However, his strong skills may have enabled his participation in the group context, which was a prerequisite for any learning to occur. Dean, despite having the weakest socialization skill, benefited the most from the structured, repetitive nature of the motor tasks, which may have been less socially demanding than unstructured play. This suggests that while social skills are important for participation, the nature of the tasks and other factors, like rigidity, may be stronger predictors of the magnitude of motor improvement in this type of intervention.

Table 2. Summary of Baseline Moderator Profiles and Motor Improvement Outcomes.

	RRBS (T0)	SRS-2 (T0)	VABS (T0)	Mean Motor Improvement	Variability of Improvement
Participant	**Reaction to Change**	**Social Motivation (T0)**	**Socialization (T0)**	**(Mean Δ%)**	**(SD of Δ%)**
Manuel	13 (High)	35 (Typical)	12	36.5%	19.1% (High)
Dean	4 (Low)	68 (Impaired)	6 (Low)	48.0%	7.1% (Low)
Gene	10 (Moderate)	64 (Impaired)	16 (High)	31.5%	16.3% (High)

Note. Higher RRBS scores indicate greater rigidity. Lower SRS-2 T-scores indicate better functioning. Mean Δ% represents the mean percentage point increase in core MOVIT capacities (Balance, Coordination) from T0 to T2. SD of Δ% represents the standard deviation of this improvement, with higher values indicating more uneven progress.

3.6. Parental Feedback

Parents provided qualitative feedback on both the project and the parent training course. Overall, their testimonies reflected high levels of satisfaction with the diversity of proposed activities (e.g., sport, theater, gym), the opportunities for their youths to engage in structured leisure, and the perceived usefulness of the parent training component in acquiring practical strategies for daily management. Regarding sports and recreational activities, several parents reported that their children particularly enjoyed gym-based sessions, which were described as motivating and effective in promoting both physical well-being and social rule learning. Gene's mother emphasized that the gym had been especially stimulating for her son, who had recently lost weight and was motivated to maintain his physical health. She highlighted that the sports context served as a natural setting to reinforce rule acceptance and frustration tolerance, particularly in relation to the ability to accept "no" during adolescence. Another mother observed that her son appeared more relaxed and less physically clumsy following participation in the gym, and she expressed hope for his inclusion in a community sports group. In terms of daily living skills and socialization, parents noted improvements in domains such as money management and autonomy. For example, one father described his son's progress in financial skills, noting that he had begun to purchase necessities independently. However, some challenges remained in orientation, using public transportation, and establishing social relationships beyond group activities. The parent training course was widely appreciated. Parents valued the opportunity to share experiences with others in similar situations, recognizing both everyday challenges and potential solutions. Several emphasized the importance of acquiring technical knowledge to understand their child's diagnosis better, communicate effectively with professionals, and apply consistent strategies across home, school, and social contexts. One mother stressed the importance of maintaining continuity between therapy and daily life, involving not only parents but also schools, relatives, and peers. She described the course as a crucial step in "recovering lost time" and in developing a coherent framework for supporting her son. Taken together, these testimonies highlight the perceived benefits of training, which provided a multi-domain intervention combining sports, expressive activities, and ABA-based strategies, while simultaneously empowering parents through structured training. Parents identified improvements in their children's autonomy, physical well-being, and socialization, as well as in their own sense of competence in managing everyday challenges.

4. Discussion

This study investigated the feasibility and preliminary outcomes of a multimodal intervention that integrated structured physical activity with behavioral strategies for three adolescents with ASD. The findings provide fascinating insights into the potential of such programs in community-based settings. The results indicate consistent improvements in motor competencies, selective reductions in specific domains of repetitive behaviors, and suggest a potential role for baseline behavioral and social profiles as moderators of intervention response. On the motor level, all participants demonstrated progress across the assessed capacities, with the most robust gains observed in intersegmental and asymmetrical coordination. These outcomes align with the existing literature confirming the effectiveness of structured PA interventions for enhancing gross motor skills in adolescents with ASD (Huang et al., 2020; Xing et al., 2025). It is noteworthy that the temporal structuring of movement, while showing improvement, proved to be the most complex domain, with the lowest absolute mastery levels. This suggests that while time-related motor planning is sensitive to intervention, it may require longer, more intensive, or more cognitively mediated training to be fully acquired. The intervention was also associated with positive, though selective, behavioral changes. The observed reductions in restricted behaviors and modulation insufficiency are consistent with prior research suggesting that PA can serve as an antecedent strategy to promote self-regulation and engagement (Neely et al., 2015; Toscano et al., 2022). Equally significant was the stability of the "reaction to change" domain. Rather than a failure of the intervention, this finding suggests that cognitive rigidity and resistance to novelty may represent a more entrenched construct, one that requires more targeted behavioral strategies beyond what a motor-centric program can provide. Perhaps the most significant contribution of this exploratory study lies in its generation of specific, testable hypotheses regarding moderators of intervention response. However, these must be interpreted with extreme caution, given the sample size. A compelling pattern emerged from the data, suggesting that intrinsic social motivation may be a key facilitator of progress. Manuel, the only participant with typical social motivation, achieved substantial motor gains despite high behavioral rigidity. This leads to the hypothesis that an intrinsic drive for social interaction may be a critical catalyst for engagement and learning in a group context. Second, the data suggest that behavioral rigidity may moderate how an individual improves, rather than if. Dean, who had the lowest rigidity score, demonstrated the most consistent and robust motor progress (lowest variability of improvement). Conversely, participants with higher rigidity showed more variable gains. This preliminary pattern supports the hypothesis that behavioral rigidity may act as a barrier to the uniform and efficient acquisition of new motor skills, leading to more fragmented learning.

4.1. Limitations

It is crucial to interpret these findings within the context of the study's significant methodological limitations. The pre-post case-series design precludes any causal inference. Improvements could be attributed to other factors, including natural maturation, concurrent therapies received at the rehabilitation center, or the Hawthorne effect. Future research should employ more rigorous designs, such as a multiple baseline across participants design, to better establish a causal link between the intervention and the observed outcomes. The minimal sample size and the heterogeneity of participants limit the generalizability of the findings. Replicating this study with a larger, more diverse sample is essential. Furthermore, the variable attendance resulted in unequal intervention dosages across participants, confounding direct comparisons of their trajectories. The reliance on parent-report measures for behavioral and adaptive data also introduces potential reporting bias.

4.2. Strengths and Implications of the Study

Despite its exploratory nature, this study possesses several key strengths that inform its practical implications. A primary strength is the integrated, multi-component intervention model, which synergistically combines evidence-based principles from both physical activity and ABA. This moves beyond simply prescribing exercise, offering a structured framework on how to teach, motivate, and generalize motor skills effectively. Secondly, the study demonstrates high ecological validity by implementing the intervention in a community-based public gym. This showcases the feasibility of translating clinical strategies into inclusive, real-world settings, a critical step for promoting long-term health and community engagement. Finally, the use of objective and granular assessment tools, such as MOVIT, alongside standardized behavioral scales, provided a multifaceted view of participant progress, allowing for a nuanced analysis that extends beyond anecdotal observation. The findings, while preliminary, offer several actionable implications for clinical, educational, and community practices. From a clinical perspective, this study offers a practical blueprint for practitioners, including Board Certified Behavior Analysts (BCBAs), physical therapists, behavior technicians, shadow school teachers, and occupational therapists, on how to integrate behavioral strategies into physical activity programs. The results support the use of structured PA as a proactive, antecedent-based intervention to reduce restrictive and repetitive behaviors, potentially decreasing the need for more reactive strategies. Furthermore, the exploratory moderator analysis suggests that a "one-size-fits-all" approach is insufficient. Clinicians should move beyond a simple diagnosis to consider an adolescent's specific behavioral profile. For example, an individual with low social motivation may require a more robust and individualized reinforcement system. At the same time, one with high behavioral rigidity may benefit from concurrently integrated flexibility training to maximize motor skill acquisition.

The community and social implications of successfully implementing this program in a public gym are significant for community inclusion. It provides a replicable model for community organizations (e.g., gyms, sports clubs, recreational centers) on how to create structured and supportive programs that are accessible to adolescents with ASD. By teaching functional motor skills in a natural environment, the intervention directly promotes skills necessary for independent community participation and lifelong wellness. This approach fosters not only physical health but also opportunities for social engagement in normative settings, challenging the common barriers to participation often faced by this population. Empowering adolescents with the competence and confidence to use community facilities can significantly enhance their quality of life and social inclusion post-education. The study's findings are highly relevant for educational settings, particularly for physical education and transition planning. The results demonstrate that integrating ABA principles—such as clear instructions, modeling, and systematic reinforcement—can make educational curricula more accessible and effective for students with ASD. The observed reduction in stereotypy following physical activity suggests that structured movement breaks could be a powerful tool for improving classroom readiness and attention to academic tasks. For older adolescents, the skills acquired are directly applicable to Individualized Education Program (IEP) transition goals, which focus on preparing students for post-secondary life. Learning to follow an exercise routine in a community setting independently is a critical life skill that supports long-term health, self-management, and social integration beyond the school system. Future research should also consider incorporating direct measures of mental health and quality of life, as the positive changes in behavior and social motivation observed here likely contribute to overall psychological well-being.

5. Conclusions

In conclusion, this study provides preliminary evidence that a structured physical activity intervention informed by ABA principles is a feasible and promising model for promoting motor and behavioral development in adolescents with ASD within a community setting. Despite its limitations, this work makes a valuable contribution by generating specific, testable hypotheses regarding the roles of social motivation and behavioral rigidity as potential moderators of treatment success. These promising but preliminary findings underscore the need for future research to replicate these results with larger samples and more robust controlled designs. Explicitly testing these moderators will be crucial for developing increasingly personalized and effective interventions that can promote the autonomy, inclusion, and quality of life for adolescents on the autism spectrum.

Author Contributions: Conceptualization, M.E. and O.R.; methodology, M.E. and O.R.; software/validation, E.P. and M.E.; formal analysis, M.E.; investigation, O.R. and E.P.; resources, M.E. and D.B.; data curation, M.E. and E.P.; writing—original draft preparation, M.E.; writing—review and editing, R.F. and M.C.; visualization, M.E.; supervision, M.M. and M.V. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Enel Cuore (https://www.enelcuore.it/progetti/articles/2025/03/autonomia-adolescenti-autismo, accessed on 4 September 2025). The activity described in the manuscript was classified as the evaluation of a special ordinary educational activity conducted within the community project Enel Cuore (Progetto Comunitaba). This was a standard, non-invasive group activity, not an experimental intervention, integrated into the pre-existing educational plan for adolescents with Autism Spectrum Disorder. In line with common institutional and national ethical guidelines in Italy—which often follow the principles set forth by the Comitato Nazionale per la Bioetica (National Bioethics Committee) and general

European frameworks—research that involves the evaluation of normal, established educational and institutional practices is typically exempt from mandatory full ethics review. This exemption is further supported by the data being collected and analyzed confidentially/anonymized.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent for publication has been obtained from participating patients who can be identified.

Data Availability Statement: Data are available upon request to the corresponding author.

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Appendix A

The table reports all training tasks implemented during the intervention, organized by functional domain. A checkmark (✓) indicates that the respective participant performed the task.

Table A1. Comparative Training Task Matrix by Domain, Sub-Capacity, and Participant.

Domain/Capacity	Sub-Capacity	Training Task	Manuel	Dean	Gene
1. Tone and Relaxing	Shift from activity to inactivity	Alternate arm circles, changing direction on the teacher's command		✓	
		Arm circles (one arm forward–backward) on verbal command		✓	
		Arm circles forward and backward		✓	✓
		Arm circles, changing direction on verbal command	✓		✓
2. Balance and General Dynamic Coordination	Balance on one foot	Balance on dominant foot, hands on hips, eyes closed, 5″			✓
		Balance on left foot 18″	✓	✓	✓
		Balance on non-dominant foot, hands on hips, eyes closed, 5″			✓
		Ball throw while balancing on one foot.	✓	✓	✓
		Maintain balance on the dominant foot, hands on the hips, eyes closed, 5″	✓	✓	
		Maintain balance on the dominant foot, hands on the hips, eyes open, 8″		✓	
		Maintain balance on non-dominant foot, hands on hips, eyes closed, 5″	✓	✓	
2. Balance and General Dynamic Coordination	Balance on tiptoes	Balance on tiptoes for 10″, eyes open, while catching and throwing a ball (2 m)	✓		
		Balance on tiptoes, eyes open, catching and throwing a ball from 2 m			✓
		Maintain balance on tiptoes, eyes open, while catching and throwing a ball from 2 m, 10″		✓	
		Stand on tiptoes, hands on hips, 10″	✓	✓	✓

Table A1. *Cont.*

Domain/Capacity	Sub-Capacity	Training Task	Manuel	Dean	Gene
2. Balance and General Dynamic Coordination	Jumps with balance	Jumps on dominant leg 8 m, curved path, inside 40 cm lane			✓
		Jumps on dominant leg 8 m, straight path, inside 40 cm lane			✓
		Jumps on dominant leg for 8 m, curved path, inside 40 cm lane		✓	
		Jumps on non-dominant leg 8 m, straight path, inside 40 cm lane			✓
		Jumps on non-dominant leg for 8 m, straight path, inside 40 cm lane		✓	
		Jumps on right foot (path 8 m)		✓	
2. Balance and General Dynamic Coordination	Running with balance	Run 20 m on a curved path with low obstacles (10–20 cm), inside a 20 cm lane.			✓
		Run 20 m on a curved path, inside a 20 cm lane.			✓
		Run about 20 m on a curved path with low obstacles (10–20 cm), inside a 20 cm lane.		✓	
		Run about 20 m on a curved path with low obstacles (10–20 cm), inside a 30 cm lane.		✓	
		Run approximately 20 m on a curved path, inside a 20 cm lane.		✓	
2. Balance and General Dynamic Coordination	Running/jumping with balance	Jumps on right foot (path 8 m)	✓		
		Jumps on the spot, bringing knees to chest, 15″	✓		
		Jumps on the spot, dominant leg 15″	✓		
		Jumps on the spot, non-dominant leg 15″	✓		
		Skipping 20″	✓		
2. Balance and General Dynamic Coordination	Runs, hops, jumps on the spot	Jumps bringing knees to chest, 15″		✓	✓
		Jumps on the spot, dominant leg, 15″		✓	✓
		Jumps on the spot, non-dominant leg, 15″		✓	✓
		Skipping 20″		✓	✓
3. Segmental Coordination	Asymmetrical arm–leg movements	Alternate arm swings (forward–backward)	✓		
		Alternate swings of arms with knee bends and head rotation	✓		
		Leg swing with same-side hand touch	✓		
		Leg swings forward, then outward		✓	
		Move one arm forward and the other backward alternately.		✓	✓
		Small jumps forward–backward (alternate legs)	✓		
		Standing, arms extended forward, open one arm then the other, and rotate your head to follow.			✓
		Standing, arms forward, open one arm, then the other, rotating head to follow		✓	
		Swing the leg outward, touch with the same-side hand, and rotate the head to the same side.			✓
		Swing one leg forward, touch with the same side, then the opposite hand.		✓	✓

Table A1. *Cont.*

Domain/Capacity	Sub-Capacity	Training Task	Manuel	Dean	Gene
3. Segmental Coordination	Head–arm coordination	Arm–head coordination task	✓	✓	✓
		Flex one leg backward, touch heel with same-side hand, rotate head to same side.	✓		
		Standing, arms forward, alternate arm swings on the sagittal plane, and rotate the head to follow the backward arm.			✓
		Standing, arms forward, alternate arm swings on the sagittal plane, rotating the head to follow the backward arm		✓	
		Swing the leg outward, touch with the same-side hand, and rotate the head to that side.		✓	
		Touch heel with the same-side hand.		✓	✓
3. Segmental Coordination	Symmetrical arm movements	Arm swings (forward–backward) + knee bends			✓
		Jumps forward–backward with alternating arm swings on the sagittal plane		✓	
		Side jumps (open–close legs) with arm swings upward on the frontal plane.		✓	
		Standing, arm swings on the frontal plane (outward), raising the head to look at the hands	✓		
		Standing, arm swings on the sagittal plane (forward), following with the head	✓		
		Standing, swing arms on the frontal plane (outward), raising head to look at hands.		✓	
		Standing, swing arms on the sagittal plane (forward), following with the head.		✓	
		Standing, swing arms on the sagittal plane, following with the head.			✓
3. Segmental Coordination	Symmetrical arm–leg movements	Jumps forward–backward with alternating arm swings on the sagittal plane			✓
		Side jumps (open–close legs) + arm swings upward from front to above, following with head.			✓
		Side jumps (open–close legs) + arm swings upward on the frontal plane, followed by the head.	✓		
		Side jumps (open–close legs) with arm swings upward on the frontal plane.		✓	
		Simultaneous arm swings (forward–backward) + knee bends	✓		
		Small jumps forward–backward (alternate legs)		✓	
4. Intersegmental Coordination	Arm–leg combined movements	Bicycle exercise	✓	✓	✓
		Side jumps (open–close legs) + arm swings upward from front to above, following with head.	✓		
		Small jumps forward–backward (alternate legs)			✓
5. Spatial Orientation	Movement in relation to peers	Run and pass peers (opposite facing direction)	✓	✓	✓
		Run and pass peers (same facing direction)	✓	✓	✓
		Run right and left, change direction on verbal request.	✓	✓	
		Run right and left, changing direction on verbal request.			✓

Table A1. *Cont.*

Domain/Capacity	Sub-Capacity	Training Task	Manuel	Dean	Gene
5. Spatial Orientation	Right–left on others	Identify the peer's right/left hand, foot, eye, and ear on verbal request	✓		
		Indicate the peer's right/left hand, foot, eye, ear (facing forward)			✓
		Indicate the peer's right/left hand, foot, eye, ear (opposite facing direction)		✓	
		Indicate the peer's right/left hand, foot, eye, ear (same facing direction)		✓	
5. Spatial Orientation	Right–left on self	Perform eight movements: touch the right/left eyes and ears with the corresponding hands.		✓	
		Perform eight movements: touch the right/left eyes and ears with the corresponding hands.			✓
5. Spatial Orientation	Spatial localization of objects	Hit the target 30 cm in diameter at 5 m (10 throws with a small ball + 10 throws with a big ball)	✓	✓	✓
		Hit the target 60 cm in diameter at 5 m (10 throws with a small ball + 10 throws with a big ball)	✓	✓	✓
		Hit teacher moving on the short side of the gym from 5 m (10 throws)		✓	✓
		Hit the teacher walking along the short side of the gym from 5 m (10 throws)	✓		
5. Spatial Orientation	Spatial memory	Perform obstacle course (as demonstrated), reproduce on paper		✓	✓
		Perform the obstacle course and reproduce it on paper.	✓		
		Play a short volleyball/ball passing game, then reproduce positions on paper.	✓		
		Run and stop when estimating a 20 m distance.	✓	✓	
		Run freely 20″ in a 9 × 9 m without colliding with 12–15 peers.	✓	✓	
		Run freely 20″ in a 9 × 9 m without colliding with peers and avoiding nine sticks.	✓	✓	
		Run in line, maintain a 2 m distance, and stop at the signal.	✓	✓	✓
		Throw a 3 kg weight and estimate the distance it travels.	✓		
		Throw a 3 kg weight and estimate the distance it travels.		✓	✓
		Walk in line, maintain a 2 m distance, and stop at the signal.	✓	✓	✓
		Walk an unfamiliar city path (100 m, two right + 2 left turns), reproduce on paper.	✓	✓	
		Walk an unfamiliar city path (100 m, consisting of two right turns and two left turns), then return to the start.	✓		

Note. This appendix reports the complete matrix of training tasks implemented during the intervention. Tasks are organized by Domain/Capacity (e.g., Tone and Relaxing, Balance and General Dynamic Coordination, Segmental Coordination, Intersegmental Coordination, Spatial Orientation) and further specified by Sub-Capacity (e.g., Balance on tiptoes, Balance on one foot, Symmetrical/Asymmetrical arm–leg movements, Right–left on self/others, Spatial memory). Each row lists the Training Task, including duration, distance, or object specifications where applicable. The final three columns indicate whether the task was assigned to each participant (Manuel, Dean, Gene) using a checkmark (✓). Rows with ✓ in more than one column represent group-level tasks, implemented jointly across participants. Rows with a single ✓ correspond to individualized tasks, tailored to the specific needs and goals of one participant. This layout enables the immediate identification of the shared "core set" of exercises and the individualized extensions provided within the structured intervention.

Appendix B

Table A2. Treatment Fidelity Data.

Session	Observation Date	Score Obtained	Max Possible Score	Fidelity %	Brief Notes
2	15 June 2021	14.5	15	96.7%	Excellent adherence.
5	6 July 2021	13.0	15	86.7%	The session was slightly rushed, with a shorter duration.
8	27 July 2021	13.0	13	100%	No challenging behaviors observed (D1, D2 = N/A).
11	17 August 2021	12.5	15	83.3%	The token economy was not systematically applied.
14	7 September 2021	14.0	15	93.3%	Excellent adherence.
18	5 October 2021	15.0	15	100%	Session implemented perfectly.
21	26 October 2021	13.5	15	90.0%	Feedback was sometimes delayed.
25	23 November 2021	12.0	15	80.0%	Minimum adherence; follow-up supervision recommended.
28	14 December 2021	14.0	14	100%	Use of time-out not required (D2 = N/A).
Average				92.2%	Overall Fidelity: HIGH

Note. To ensure the intervention was implemented as designed, a supervisor (or an independent second observer) completed a treatment fidelity checklist for nine sessions (approximately 30% of the total sessions), selected randomly throughout the study. Scoring Methodology: Each checklist item was scored as follows: Yes = 1, Partially = 0.5, No = 0. N/A (Not Applicable): If an item was not applicable during a session (e.g., no challenging behaviors occurred, making items D1 and D2 not assessable), it was excluded from the total possible score for that session. For instance, if two items were marked N/A, the maximum possible score for that session was 13 instead of 15. Formula: Fidelity (%) = (Score Obtained/Maximum Possible Score) × 100.

Table A3. Fidelity Data Sheet (Example 1: Session 2).

Component	Item	Response	Score	Notes/Details
A. Structural				
A1 Setting	Session held in a public gym?	Yes	1	
A2 Duration	Duration was ~2 h?	Yes	1	
A3 Staff	Trainer + tech present?	Yes	1	
A4 Supervision	BCBA supervision conducted?	N/A		Not a supervision day.
B. Procedural				
B1 SPA	Preference assessment conducted?	Partially	0.5	Conducted informally.
B2 Clear Instructions	Clear instructions provided?	Yes	1	
B3 Modeling	Exercise demonstrated?	Yes	1	
C. Behavioral				
C1 Social Praise	Social praise used?	Yes	1	
C2 Immediate Feedback	Immediate feedback provided?	Yes	1	
C3 Token Economy	Token economy implemented?	Yes	1	
D. Behavior Management				
D1 Antecedent Strategy	Rules re-explained for minor issues?	Yes	1	
D2 Time-Out	Time-out reserved for severe behavior?	Yes	1	
E. Data Collection				
E1 Activity Tracking	Activities logged in the matrix?	Yes	1	
E2 Parameter Recording	Parameters recorded?	Yes	1	

Note. The table provides a detailed look at how scores were derived and the calculation of Total Score: 14.5/15 (Fidelity: 96.7%).

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