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IMPACT OF PLYOMETRIC EXERCISE ON BALANCE REGULATION IN CHILDREN AND YOUTH WITH AUTISM SPECTRUM DISORDER

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ABSTRACT. ***Background*:** Motor coordination difficulties and impaired postural stability are commonly observed in children and adolescents with Autism Spectrum Disorder (ASD), often limiting their ability to engage in everyday physical tasks and recreational activities. Although numerous strategies have been implemented to address these motor impairments, the specific impact of plyometric exercise on balance outcomes in this population has not been thoroughly examined**.** ***Objective**:* This research aimed to evaluate the influence of a systematically designed plyometrictraining program on balance control in school-aged individuals with ASD. ***Methods**:* Thirty participants (15 control group, 15 experimental group) between the ages of 10 and 15 years, all formally diagnosed with ASD, took part in a 12-week intervention. 15 children participated in plyometric exercise sessions; 15 children did not attend any form of exercise session during the 12 weeks. Pre- and post-training assessments were conducted using two standardized tools: the Mini Balance Evaluation Systems Test (Mini-BESTest) and the balance component of the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2). ***Results**:* Statistical analysis demonstrated that the group undergoing plyometric training exhibited significant enhancements in both static and dynamic balance when compared to the control group, with results showing a p-value of less than 0.05. ***Conclusion**:* The findings suggest that plyometric training can serve as a beneficial and motivating approach to support balance development in children and adolescents on the autism spectrum.

Keywords: balance, autism spectrum disorder, visually impaired

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INTRODUCTION

Recent research suggests that Autism Spectrum Disorder (ASD) affects more than just communication, cognition, and emotional regulation—it also significantly impacts motor control (American Psychiatric Association, 2013). Although motor difficulties are not part of the core diagnostic criteria for ASD, they are frequently observed and often resemble those seen in developmental coordination disorder (DCD) (Sumner et al., 2016). Such motor challenges in early childhood can hinder participation in physical activities with peers, thereby reducing opportunities for social engagement and developmental progression.

From a cognitive science perspective, motor difficulties in ASD can be understood through disruptions in sensory processing, cognitive motor planning, and the timing and sequencing of muscle activation. Studies have indicated that individuals with ASD may experience impairments at each of these levels, which collectively contribute to challenges in motor coordination and execution (Stins & Emck, 2018).

Upright standing is a complex, highly regulated process that involves both open- and closed-loop control mechanisms (Collins & De Luca, 1993). While the body maintains near-equilibrium during quiet standing, it must constantly respond to internal and external disturbances through postural adjustments. These responses depend on the integration of multisensory input to determine body orientation, along with appropriate motor outputs to maintain or regain balance. Importantly, balance control is not solely governed by spinal reflexes—it also engages higher-order brain structures, including the motor cortex, cerebellum, basal ganglia, vestibular cortex, and brainstem. In individuals with ASD, multiple studies have shown that postural control is often impaired, and that these impairments can correlate with the severity of ASD symptoms (Stins & Emck, 2018).

Plyometric exercise, which involves rapid movements utilizing the muscle stretch-shortening cycle, has been shown to enhance both static and dynamic balance (Kons et al., 2023). Research indicates that plyometric training—whether horizontal or vertical—can significantly enhance stabilization in trained individuals, such as young athletes (Granacher and Behm, 2023), and improve their ability to respond effectively to perturbations (Moran et al., 2021)

The objective of the present study was to evaluate the effectiveness of a systematically structured plyometric training program in improving static and dynamic balance control in school-aged children with autism spectrum disorder (ASD).

MATERIAL AND METHODS

Participants

A total of 30 children with ASD (16 females and 14 males), aged between 10 and 15 years, were recruited from a local school. Eligibility criteria included no prior involvement in structured balance training and the capacity to respond to clear verbal commands. Written informed consent was obtained from the participants' legal guardians before study enrolment.

Procedure

The intervention consisted of a systematically designed plyometric training program implemented over a 12-week period, 2 sessions a week, 50 minutes per session. The program included age-appropriate plyometric exercises such as vertical and horizontal jumps, squat jumps, lateral jumps, hopping drills, and controlled landing tasks. These exercises were selected to stimulate the stretch–shortening cycle and improve neuromuscular performance.

The training protocol was specifically structured to target both static and dynamic balance. Static balance was addressed through exercises requiring postural stabilization following landing phases and controlled single-leg stance positions. Dynamic balance was developed through movement-based plyometric tasks involving directional changes, coordinated jumping sequences, and controlled body displacement.

Exercise intensity and complexity were progressively adjusted according to participants' capabilities to ensure safety and optimal adaptation. All sessions were conducted under professional supervision to ensure correct technique and minimize injury risk.

Static and dynamic balance were assessed before and after the intervention using standardized testing procedures.

Materials

The Mini Balance Evaluation Systems Test (Mini-BESTest) and the balance component of the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2) was used to assess balance (Baldwin, Kinsella, & Byrne, 2024).

Data analysis

Statistical analysis was performed using the MedCalc® Statistical Software version 23.3.7 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2025). Data were characterized by mean and standard deviation. Comparisons between measurements were performed using the two-way repeated measures ANOVA. The p value <0.05 was considered statistically significant.

RESULTS

The following section presents the quantitative outcomes of the 12-week plyometric training intervention on balance performance in school-aged children with ASD. Pre- and post-intervention measurements for static and dynamic balance were obtained using the Mini Balance Evaluation Systems Test (Mini-BESTest) and the balance subscale of the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2). Descriptive statistics (means ± standard deviations) and inferential analyses, including paired and independent samples tests, were conducted to evaluate within-group and between-group differences. Statistical significance was set at $p < 0.05$. The results are reported to assess the efficacy of plyometric training in enhancing balance outcomes relative to a non-exercising control group.

Following the data analysis, no statistically significant change was observed in the control group (Table 1).

Table 1. The Balance Evaluation Systems Test (BESTest)for the control group

	Mean	St. deviation	N
INITIAL	16.00	1.690	15
FINAL	15.87	1.767	15

The experimental group showed statistically significant differences between the baseline and post-intervention assessments p≤0, 05 (Table 2).

Table 2. The Balance Evaluation Systems Test (BESTest)for the experimental group

	Mean	St. deviation	N
INITIAL	16.00	1.309	15
FINAL	21.20	1.971	15

When comparing the groups, no significant differences were observed at the initial assessment. However, at the final evaluation, following the 12-week intervention, a statistically significant difference was found between the control group and the experimental group p≤0, 05 (Table 3).

Table 3. The Balance Evaluation Systems Test (BESTest)

	Control group		Experimental group	
	Mean	St.dev	Mean	St.dev
INITIAL	16.00	1.690	16.00	1.309
FINAL	15,86	1.767	21.20	1.971

Note: p≤0, 05

Following the data analysis, no statistically significant change was observed in the control group (Table 4).

Table 4. The BOT-2 for the control groupl group

Mean	St. deviation	N	
INITIAL	22.80	3.278	15
FINAL	22.93	3.105	15

The experimental group showed statistically significant differences between the baseline and post-intervention assessments p≤0, 05 (Table 5).

Table 5. The BOT-2 for the experimental group

Mean	St. deviation	N	
INITIAL	22.93	3.011	15
FINAL	32.93	2.374	15

When comparing the groups, no significant differences were observed at the initial assessment. However, at the final evaluation, following the 12-week intervention, a statistically significant difference was found between the control group and the experimental group p≤0.05 (Table 6).

Table 6. The BOT-2. Comparation between the groups

	Control group		Experimental group	
	mean	St.dev	mean	St.dev
INITIAL	22,80	3.278	22,93	3.011
FINAL	22,93	3.105	32,93	2.374

Note: p≤0, 05

DISCUSSION

Children and adolescents with ASD often experience impairments in balance and motor control. Postural control difficulties are well-documented: poorer performance in static and dynamic balance tasks relative to neurotypical peers; more sway in center-of-pressure measures; and associations between severity of core autism features (e.g. repetitive behaviors) and poorer motor control (Favilene et al 2025).

Because balance is foundational to many motor skills and daily functioning (walking, coordination, fall prevention), interventions aimed at improving balance are considered important in ASD. Exercise-based interventions broadly have shown benefit. For example, a meta-analysis of 12 randomized

control trial (children with ASD aged 3-18) found that exercise interventions significantly improved balance (standardized mean difference ~ 0.86, $p < 0.05$). Importantly, interventions longer than eight weeks had stronger effects (Li, H., & Zhang, R. 2025). Another meta-analysis of 15 studies (195 participants) found large positive effects for balance interventions in ASD (Djordjević et.al.2022).

Plyometric training (jumping, bounding, rapid stretch-shortening of muscles) is well-known in sports and rehabilitation settings for improving power, agility, and sometimes balance or stability. In populations with motor impairments (e.g., cerebral palsy), plyometric jump or combined plyometric-jump training has been found to significantly improve both static and dynamic balance. For example, a recent meta-analysis in youth with cerebral palsy (ages 9-15) found that plyometric jump training over 8-12 weeks (2-4 sessions per week) resulted in moderate effect size improvements in static and dynamic balance compared to controls (Garcia-Carrillo et al 2024).

In non-clinical populations, combining plyometric with balance training tends to yield larger improvements in dynamic balance and related motor performance compared to plyometric alone or standard practice. For instance, in adolescent Taekwondo athletes, a combined balance + plyometric (PT) intervention produced superior gains in dynamic balance (as measured by stability indices) compared to PT alone (Shen X. 2024). Also, in children, combining plyometrics + balance yielded better outcomes for static & dynamic balance, agility, etc., than plyometric only (Chaouachi et al 2014).

While the general exercise-balance literature for ASD is fairly robust, there appears to be little or no published research specifically applying plyometric training protocols to ASD populations (at least none identified in recent meta-analyses or trials I located). Most ASD studies focus on more traditional balance training (biofeedback, virtual reality, physical education programs, or general motor skills), not explosive or high-velocity stretch-shortening movements like plyometrics. For example:

- Biofeedback-based videogame or VR-based balance training has shown improvements in balance measures, postural sway, and even some reductions in autism symptom severity (Travers et al 2018).
- A six-month extracurricular physical education program improved dynamic balance in ASD children (Salvador-Garcia et al 2023).
- Pilates-style movement intervention showed benefit for flexibility and balance in ASD (Saraçoğlu & Şirinkan 2016).

Thus, there is a gap in exploring plyometric training in ASD: its safety, efficacy, and how its intensity or volume needs to be adapted.

In the present study, the experimental group demonstrated significant improvements in dynamic balance following a structured 12-week plyometric

training program. The program was designed to progressively challenge lower limb strength, coordination, and neuromuscular control through a variety of bodyweight plyometric exercises. These included jumping in place, jumping up onto a bench, jumping down from a bench, jumping on one leg in place, as well as single-leg jumps onto and off a bench.

This combination of bilateral and unilateral plyometric tasks provided graded exposure to the stretch-shortening cycle, requiring participants to develop both explosive power and postural stability. Importantly, exercises such as jumping down and up from a bench demanded eccentric control and reactive balance during landing and takeoff, likely contributing to the observed improvements in dynamic postural control.

Post-intervention assessments revealed that the experimental group had enhanced performance in balance tasks—particularly those requiring dynamic weight shifts and single-leg stability—relative to their pre-test baseline and the control group. These findings align with previous studies showing that plyometric training improves dynamic balance in typically developing children and athletes (Hammami et al., 2016; Chimera et al., 2044), although the present study is, to our knowledge, among the first to apply such a program in children with Autism Spectrum Disorder (ASD).

Given that individuals with ASD often exhibit impaired balance and sensorimotor integration (Fournier et al., 2010; Li et al et al., 2023), these results suggest that appropriately tailored plyometric training may serve as a viable and effective intervention to target these deficits.

The improvements observed after 12 weeks are also consistent with meta-analytic findings indicating that intervention duration greater than 8 weeks is typically required to produce measurable gains in balance among children with ASD (Wang et al., 2024).

CONCLUSIONS

The findings of this study demonstrate that a 12-week plyometric training program led to significant improvements in balance performance as measured by the Mini-BESTest and BOT assessments in the experimental group. In contrast, the control group showed no significant changes over the same period. These results suggest that plyometric training is an effective intervention for enhancing balance, coordination, and overall motor performance in the studied population. The lack of progress in the control group further emphasizes the impact of targeted physical training in achieving functional gains. Future studies should explore the long-term effects and optimal parameters of plyometric programs across different age groups and functional levels for children with ASD.

AUTHOR CONTRIBUTIONS

Author 1and 2 contributed to the design and implementation of the research, author 1 and 2 contributed to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this study.

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