The Efficiency of Physical Exercises in Static and Dynamic Balance in Children with High-Functioning Autism Spectrum Disorder: A Single-Blind Randomized Clinical Trial

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Abstract

Introduction: This study aims to investigate how physical activities can help enhance static and dynamic balance in children with high functioning Autism Spectrum Disorder (ASD), who often experience difficulties with communication, cognitive abilities, and motor skills. **Materials and Methods:** The study is a randomized, single-blind clinical trial examining the impact of physical activities on static and dynamic balance in 6-12-year-old hildren with high-functioning ASD from Tehran's rehabilitation centers and special schools. Initially, 30 participants were chosen, then divided into two groups of 15 using block randomization. The intervention group underwent 24 sessions of physical exercises in 8 weeks, 3 sessions per week, and the control group followed their routine therapies as before while their balance was assessed using force plate tools and the Walking heel to toe test before and after the interventions. **Results:** Findings indicated that static and dynamic balance in children with high function ASD improved significantly by physical activities (P<0.05). The center of pressure sway decreased significantly in lateral displacement (P=0.001), Anterior-Posterior displacement (P=0.002), mean velocity of sway (P=0.003), and sway area (P=0.004), demonstrating improved stability and control. Moreover, the walking heel to toe test score improved significantly in the intervention group compared to the control group (P<0.001). **Conclusion:** It seems that physical activities can improve static and dynamic balance in children with high function ASD, so therapists can use physical activities to increase balance and improve movement disorders in children with high functioning ASD.

Keywords: Autism Spectrum Disorder; Physical Activity; Postural Balance

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Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder with social and communication deficits, repetitive behaviors, and strong genetic links, affecting 1 in 59 children, more so in males (1). Motor skill difficulties occur in 50-85% of children with ASD, often continuing as they age (2). Motor disorders of children with ASD including delayed development, dyspraxia, altered muscle use, balance problems, and displacement defects. Engaging in physical activities can help children with ASD to improve balance and address movement disorders (3).

The cerebellum, a crucial part of the brain, plays a significant role in maintaining balance, coordination, speech, and movement control by sensory processing of the information received from the spinal cord. Research has shown that individuals with ASD may have deficits in cerebellar function, leading to issues with situational control and postural stability. Balance, which involves sensory inputs and the central nervous system's integration, is a dynamic process crucial for maintaining proper alignment and stability. In children with ASD, there may be impairments in the multi-sensory processing necessary for controlling situations and maintaining balance (4-7).

According to a systematic review by Farahani *et al* (8) children with ASD often experience movement challenges in comparison to typically developing peers,. A recent study by Dong *et al*. (9) found that around 80% of children with ASD encounter difficulties in motor skills like manual dexterity, ball skills, and balance, affecting their overall performance. Despite these issues significantly impacting academic, social, and communication development, they are frequently overlooked and insufficiently addressed in therapy strategies.

Maintaining balance relies on the coordination of the central nervous system, sensory inputs, and the interaction between the nervous and skeletal-muscular systems. children with ASD often exhibit challenges in this process (4). Various studies have highlighted movement problems and motor delays in children with ASD, which can impact their overall development (8, 10-13). A study by Date *et al*. (4) which reviewed effective balance interventions through 21 studies, reported effective methods as diverse as animal-assisted therapies and physical activity programs. However, the number of study samples and the quality of implementation were variable, requiring more accurate assessment tools for definitive results. Hynes and Block's systematic study across 29 studies described six types of physical activity interventions for children and youth with ASD, including swimming, cycling, neuromuscular training, yoga, exercise, and exergaming, which improved physical fitness, cognition, social skills, and behavior (14). Djordjevi´c and colleagues' systematic review of 15 exercise-based intervention studies focused on balance in children and adolescents with ASD, showing a significant positive impact on balance. Despite these positive outcomes, the studies had limitations such as small sample sizes, lack of randomization, and insufficient details on diagnostic methods and assessment tools (15). Another study investigated the effect of these interventions on motor skills in 23 children with Developmental Coordination Disorder(DCD) during individualized and group therapy, showing a significant decrease in the movement assessment test for children (16).

While physical activity interventions have shown positive effects on balance in individuals with ASD, there are limitations in existing research, such as small sample sizes and lack of using objective assessment tools. A current study is focusing on an exercise programs to improve static and dynamic balance after eight weeks in individuals, aiming to address previous research limitations and determine the impact of physical factors on balance in high-functioning ASD children.

Material and Methods

This study was a single blind randomized clinical trial including 30 high function children with ASD aged 6 to 12 years attending rehabilitation centers or special schools for children with ASD in Tehran, Iran. The sample size was calculated based on the results of the modified Wisconsin card sorting test, considering the test power of 80%, confidence level of 95% and 10% sample size drop. Based on this, the sample size included 15 children in each of the intervention and control groups. The present study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (IR.SBMU.RETECH.REC.1401.567) and registered in the Clinical Trial System of Iran (IRCT20221214056817N1).

The treatment programs in the intervention group included performing physical activities in a 45-minute session, 3 days a week for 8 weeks. This program included several categories of different exercises aimed at improving agility, balance, central stability and movement coordination. The different parts of this program include tilt-board exercises, jumping and standing on one leg in the area of balance and agility; Sit-up exercise and anti-gravity exercises in the area of central stability and jumping jack and various ball activities in the field of motor coordination. In this program, with the increase in the number of treatment sessions and the increase in children's skills in doing activities, the difficulty level of the exercises increased. To be included in the study, the diagnosis was based on psychiatric decision and for determination of level of ASD the Gilliam Autism Rating Scale (GARS-3) was used respectively. Exclusion criteria were orthopedic issues affecting balance, vision and hearing problems (except for glasses and hearing aids), use of balance-impacting drugs or aids, co-occurring psychiatric disorders, non-cooperation, frequent absences, or simultaneous participation in other occupational therapy programs.

Procedure

Data collection involved collaborating with Tehran's exceptional education department and obtaining permits. From a pool of 100 children with ASD in exceptional schools and private occupational therapy clinics in Tehran, 30 were selected based on inclusion criteria.

The randomization process was based on block randomization, where participants were divided into two groups of 15 using a predefined randomization schedule. To ensure the integrity of the study, the examiner was blinded to the group assignment (control or treatment), thereby minimizing potential biases in the assessment and analysis of the outcomes.

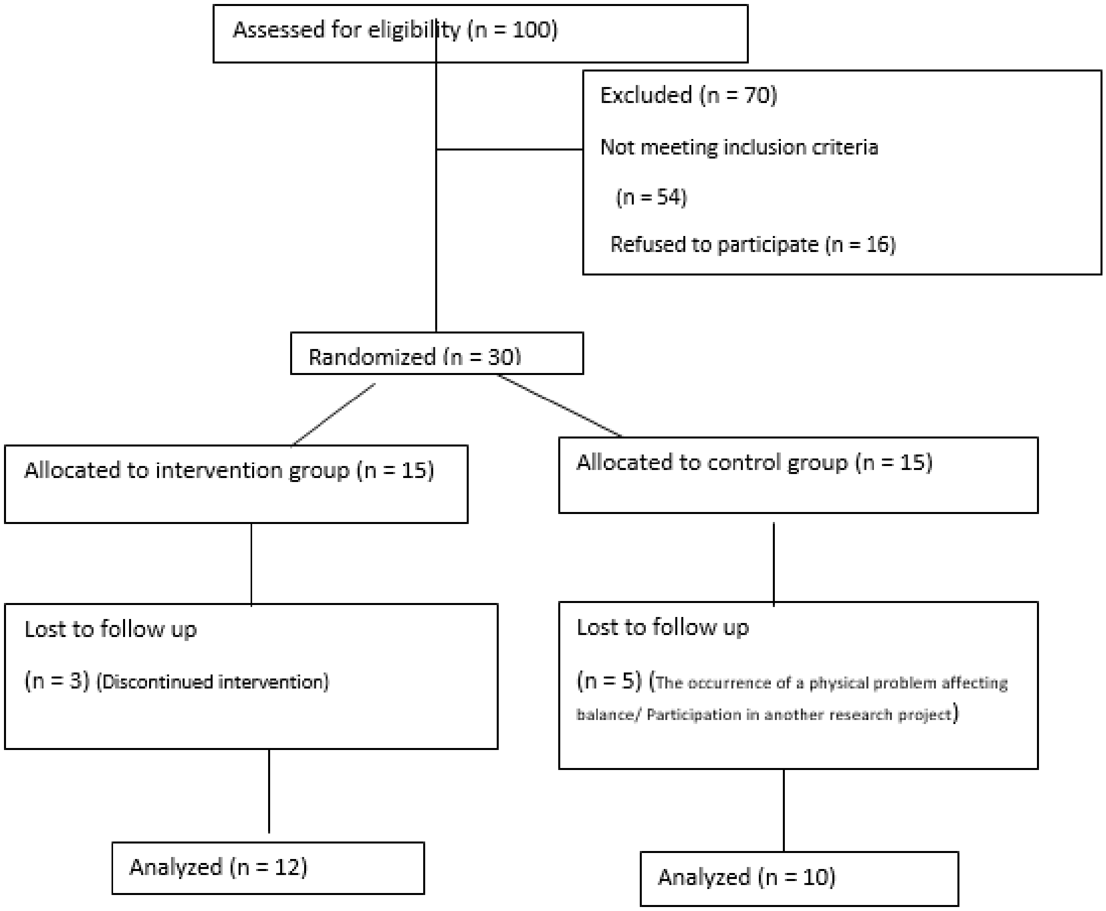

Figure 1. CONSORT diagram of the study

Due to various reasons, some participants dropped out, leaving 12 in the intervention group and 10 in the control group. Ultimately, 22 participants' data were analyzed for the study (Figure 1).

Outcomes

1. Static balance: Force Plate device, manufactured by Bertec Company (Columbus, Ohio, USA) and model series 9090, was used to measure static balance. Participants stood on the device's screen without socks, facing forward with a stationary trunk, for 20 seconds. Balance was assessed in six modes, including various leg and eye conditions. Each participant repeated these conditions three times for 20 seconds each, with a one-minute break between repetitions. If a participant displayed challenging behaviors or lost concentration, the test was repeated in those conditions. The software extracted data from the first 5 seconds, the middle 15 seconds, and the last 5 seconds of the 20-second trials. MATLAB software was used to analyze the data, calculating parameters such as Sway area, Anterior-Posterior (AP) and Medio-Lateral (ML) displacement of COP.

2. Dynamic balance: Heel to Toe Walking Test evaluated dynamic balance. Participants were asked to walk in a straight line for 15 steps, following a specific pattern. If they deviated from the path before completing 15 steps, the test was stopped, and the number of steps taken was recorded as their score. The test was performed twice, and the best score was considered the subject's record (17, 18).

Data analysis

The normality of the data set was evaluated using the Kolmogorov-Smirnov test. Descriptive and inferential statistics were used for data analysis using SPSS-25 software (IBM Corp, and Armonk, NY, USA). Descriptive statistics were then utilized to determine the mean, standard deviation, frequency, and percentage of the data. To assess the effectiveness of a physical exercise program on static and dynamic balance in children with ASD, independent t-tests and Mann-Whitney tests were employed. As normality was confirmed in both groups, independent t-tests were used; otherwise, non-parametric Mann-Whitney tests were applied for comparison.

For within-group comparisons before and after the intervention, paired t-tests were utilized as normality held in both groups, and otherwise, non-parametric Wilcoxon tests were applied. A significance level of less than 0.05 was considered for determining statistical significance in this analysis.

Results

The mean and standard deviation of age (yr), height (cm), weight (kg) and body mass index (BMI) in the intervention group were 9.16±1.94, 128.33±6.02,41.46±5.46and 32.69±26 respectively and in the control group it was 8.5±1.84, 127±5.22, 26±5.22 and 15.93±2.76 respectively. The independent t-test showed that there was no significant difference in demographic variables mentioned in the two groups (P>0.05).

The results of assessing the effectiveness of a physical exercise program on static and dynamic balance in children with ASD displayed in Tables 1 and 2.

Inter-Group Results

There was no significant difference in demographic variables (age, height, weight, and BMI) between the control and intervention groups (P>0.05). Also, there was a significant decrease in ML displacement score in the closed-eyed standing on two feet posture between the control and intervention groups after the intervention (P<0.001). Additionally, there was a significant decrease in ML displacement score in the closed -eyed standing on one foot (non-dominant foot) posture between the control and intervention groups after the intervention (P<0.05). And there was a significant decrease in AP displacement score in the closed -eyed standing on one foot (non-dominant foot) posture between the control and intervention groups after the intervention (P<0.05). About dynamic balance, there was a significant increase between the control and intervention groups after the intervention (P<0.001)

Intra-Group Results

In the control group:

There was no significant change in ML displacement scores in control group. In addition, there was no significant change in AP displacement scores in control group. About dynamic balance, there was no significant change in control group.

In the intervention group:

There were significant decreases in ML displacement scores in several postures, including open-eyed standing on two feet (P<0.05), closed-eyed standing on two feet (P<0.05), open-eyed standing on one foot (non-dominant foot) (P<0.001), and open-eyed standing on one foot (dominant foot) (P<0.05) before and after the intervention. Also, there were significant decreases in mean velocity scores in several postures, including open-eyed standing on two feet (P<0.05), closed-eyed standing on two feet (P<0.05), open-eyed standing on one foot (non-dominant foot) (P<0.05), and open-eyed standing on one foot (dominant foot) (P<0.05) before and after the intervention. Additionally, about dynamic balance there were significant increase (P<0.05).

Discussion

The findings of this study demonstrate that the physical exercise program had a significant positive impact on both static and dynamic balance in children with ASD. The results showed that the intervention group exhibited significant improvements in various balance measures, including lateral displacement, AP displacement, swing range, and average speed of swing. These improvements were observed in multiple standing positions, including standing on one and two legs, with eyes open and closed, and during blindfolded standing.

The observed improvements in balance are consistent with previous research highlighting the effectiveness of physical interventions in improving balance in children with ASD (15, 19-21). For instance, Rosca *et al.* found that a program based on physical exercise led to improved balance in children with ASD, specifically in terms of COP sway in the sway area parameter (21). However, unlike our study, they did not observe significant decreases in AP swing, lateral swing, and average swing speed. This discrepancy may be attributed to differences in assessment tools, conditions, or treatment programs used in each study.

In contrast, Chaldavi *et al.* reported significant decreases in COP oscillation in all parameters of AP displacement, lateral displacement, and average velocity of oscillation [20]. While our study did not observe similar results in these specific parameters, it is possible that the differences may be attributed to variations in the assessment tools or conditions employed. Nevertheless, both studies underscore the importance of considering individual differences and potential variability in response to balance interventions.

The present study's findings are also consistent with the review conducted by Djordjevic *et al.* (15) which highlighted the overall positive impact of balance interventions on children and adolescents with ASD. The review emphasized

Table 1. The findings of these evaluations for static balance

Variables and Conditions	Time	Mean (SD)		P-value	
		Control	Intervention	Intra group	Inter group
ML Disp (cm) OB	Pre-test	2.10 (0.94)	2.41 (1.24)	0.343	0.538
	Post-test	2.00 (0.79)	1.58 (0.79)	0.041*	0.346
ML Disp (cm) CB	Pre-test	2.89 (1.59)	2.51 (1.38)	0.336	0.564
	Post-test	3.10 (1.38)	1.08 (0.66)	0.011*	<0.001
ML Disp (cm)OO (non-dominant)	Pre-test	5.50 (3.50)	5.33 (3.39)	0.209	0.911
	Post-test	4.80 (2.82)	3.16 (2.69)	0.005*	0.107
ML Disp (cm) OO (dominant)	Pre-test	4.80 (2.14)	5.16 (0.199)	0.104	0.674
	Post-test	3.90 (1.79)	4.00 (1.34)	0.048*	0.883
ML Disp (cm) CO (non-dominant)	Pre-test	7.30 (3.52)	7.83 (3.18)	0.1	0.628
	Post-test	7.20(3.64)	4.16 (1.02)	0.006*	0.017*
ML Disp (cm) CO (dominant)	Pre-test	6.80 (2.74)	6.16 (2.69)	0.627	0.388
	Post-test	7.40 (3.86)	5.16 (3.29)	0.166	0.206
AP Disp (cm) OB	Pre-test	1.45 (0.59)	2.11 (1.37)	0.414	0.509
	Post-test	1.35 (0.47)	2.16 (1.80)	0.183	0.628
AP Disp (cm) CB	Pre-test	2.30 (0.67)	2.75 (1.28)	0.083	0.346
	Post-test	2.00 (0.47)	1.25 (0.75)	0.010*	0.030*
AP Disp (cm) OO (non-dominant)	Pre-test	4.80 (1.39)	5.16 (2.16)	0.257	0.674
	Post-test	5.10 (1.72)	2.08 (1.31)	0.046*	0.001*
AP Disp (cm) OO (dominant)	Pre-test	4.35 (1.29)	4.00 (2.82)	0.506	0.707
	Post-test	4.70 (1.76)	2.41 (1.72)	0.017*	0.007*
AP Disp (cm) CO (non-dominant)	Pre-test	7.90 (2.13)	7.75 (4.20)	0.039	0.821
	Post-test	6.10 (3.10)	3.25 (2.17)	0.008*	0.049*
AP Disp (cm) CO (dominant)	Pre-test	6.00 (3.01)	6.33 (3.20)	0.148	0.805
	Post-test	5.50 (2.32)	3.83 (2.75)	0.033*	0.046*
Sway area (cm2) OB	Pre-test	9.10 (5.42)	9.75 (4.71)	0.581	0.974
	Post-test	8.80 (4.84)	6.16 (3.29)	0.011*	0.146
Sway area (cm2) CB	Pre-test	12.60 (6.89)	13.16 (7.12)	0.341	0.821
	Post-test	13.15 (6.33)	8.33 (4.55)	0.012*	0.049*
Sway area (cm2) OO (non-dominant)	Pre-test	14.70 (9.05)	14.25 (5.44)	0.047	0.887
	Post-test	13.30 (7.84)	10.33 (8.60)	0.048*	0.412
Sway area (cm2) OO (dominant)	Pre-test	14.10 (5.30)	13.16 (6.78)	0.980	0.872
	Post-test	14.80 (8.09)	9.16 (7.83)	0.033*	0.114
Sway area (cm2) CO (non-dominant)	Pre-test	17.10 (10.25)	18.16 (9.72)	0.109	0.806
	Post-test	15.30 (8.28)	12.25 (5.81)	0.014*	0.283
Sway area (cm2) CO (dominant)	Pre-test	16.20 (8.57)	17.33 (7.67)	0.569	0.747
	Post-test	16.20 (8.57)	11.16 (6.73)	0.074	0.139
Mean velocity (cm/s) OB	Pre-test	7.10 (3.54)	6.91 (2.84)	0.648	0.923
	Post-test	6.70 (2.83)	4.08 (1.56)	0.028*	0.021*
Mean velocity (cm/s) CB	Pre-test	7.60 (3.74)	7.58 (2.74)	0.443	0.821
	Post-test	7.20 (3.22)	3.25 (1.42)	0.012*	0.006*
Mean velocity (cm/s) OO (non-dominant)	Pre-test	11.60 (5.48)	9.75 (4.76)	0.095	0.407
	Post-test	9.80 (4.28)	5.41 (2.57)	0.002*	0. 008*
Mean velocity (cm/s) OO (dominant)	Pre-test	9.10 (4.43)	10.50 (3.42)	0.063	0.539
	Post-test	9.60 (3.62)	7.08 (3.23)	0.008*	0.101
Mean velocity (cm/s)CO (dominant)	Pre-test	12.00 (5.49)	10.08 (6.18)	0.395	0.228
	Post-test	11.40 (4.35)	6.25 (2.89)	0.029*	0.036*
Mean velocity (cm/s) CO (non-dominant)	Pre-test	14.40 (6.11)	14.80 (6.42)	0.317	0.974
	Post-test	15.25 (7.56)	10.16 (3.61)	0.014*	0.036*

*SD= Standard Deviation; ML=Mediolateral; AP=Anterorposterior; Disp=Displacement; eyes open, standing on both feet (OB); eyes closed, standing on both feet (CB); eyes open, standing on one foot (OO); eyes closed, standing on one foot (CO); *=statistically significant (P≤0.05)*

Table 2. The findings of these evaluations for dynamic balance

Variable	Time	Mean(SD		*P*-value	
		Control	Intervention	Intra group	Inter group
Dynamic Balance	Pre-test	12.6(2.36	12.83(2.24	0.39	0.81
	Post-test	12.2(2.78	14.66(0.65	0.04*	0.005*

that engaging in physical activities can lead to improvements in central and lower limb muscle strength, enhancement of balance, and establishment of equilibrium within the body (17, 21, 22). Our study provides further evidence supporting this notion by demonstrating significant improvements in balance measures following an 8-week physical exercise program.

The results of this study have important implications for the development of evidence-based interventions for improving balance and overall motor skills in children with ASD. The findings suggested that a specific physical exercise program can be an intervention strategies for enhancing balance abilities in this population. Future studies should aim to replicate these findings and explore the potential mechanisms underlying these improvements. Additionally, future research should investigate the optimal duration and intensity of physical exercise programs for maximizing balance outcomes in children with ASD.

Moreover, it is essential to consider the potential moderating factors that may influence the effectiveness of balance interventions. For instance, individual differences in sensory processing, motor abilities, and cognitive functioning may impact response to physical exercise programs. Future studies should aim to identify these factors and develop personalized interventions tailored to meet the unique needs of each child with ASD.

In conclusion, this study demonstrates the effectiveness of a specific physical exercise program in improving static and dynamic balance in children with high functioning ASD. The findings are consistent with previous research highlighting the positive impact of physical interventions on balance abilities in this population. The results have important implications for the development of evidence-based interventions aimed at enhancing motor skills and overall well-being in children with ASD. Future research should aim to build upon these findings and explore the potential mechanisms underlying these improvements.

Conclusion

The study indicates that a physical exercise program affected static and dynamic balance in children with high functioning ASD, leading to improvements in various balance aspects, such as lateral and AP displacement. These benefits were particularly evident in the intervention group compared to the control group, aligning with existing literature on physical interventions for children with ASD.

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Ethical consideration

This study was conducted following all relevant ethical guidelines and regulations to ensure the protection of participants' rights and confidentiality. (Ethical code: IR.SBMU.RETECH.REC.1401.567)

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Conflict of Interest

None.

Author Contribution

MH: data curation, formal analysis, investigation, and methodology, writing, original draft. AJ: supervision, resources, and writing, original draft MH: resources, and writing, original draft, AB: formal analysis, investigation, and methodology; MKh: writing, review, and editing.

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