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Two-week trampoline intervention improves anxiety and motor performance in children with autism spectrum disorder: A randomized controlled feasibility study

Bin Luo[a] | Sawitri Wanpen[b] ✉ | Wichai Eungpinichpong[b] | Kurusart Konharn[b] | Aree Rattanathongkom[c]

[a]Exercise and Sport Sciences, Khon Kaen University, Khon Kaen 40002, Thailand.
[b]Associated Medical Sciences, Khon Kaen University, Khon Kaen 40002, Thailand.
[c]Department of Pediatrics, Faculty of Medicine, Khon Kaen University, Khon Kaen, 40002, Thailand.

Abstract: Autism Spectrum Disorder (ASD) often leads to anxiety and social and motor issues. There is a research gap in comprehensive ASD interventions. This study used a randomized controlled trial to explore the effects of a two-week trampoline exercise on children with ASD aged 9 - 12. 12 children were divided into an intervention and a control group. The intervention group did trampoline training 3 times a week for 30 minutes. Results showed that the heart rate variability HRV in the intervention group dropped significantly ($p = 0.0009$), indicating anxiety relief. One-leg standing with eyes closed (OLS) improved ($p < 0.05$), and the standing long-jump (SLJ) extended significantly ($p = 0.02$), showing better lower limb power and balance. There were no significant changes in body mass index(BMI). Trampoline exercise seems to be an effective non-pharmacological intervention for children with ASD, improving mental health and motor skills. However, long-term effects are unknown, given the small sample size and short intervention. More long-term studies are needed to explore its impact on social and cognitive functions.

Keywords: trampoline exercise, ASD, anxiety, height-for-weight percentage, lower explosive power, balance

1. Introduction

Autism spectrum disorder (ASD) is a common neurodevelopmental disorder with complex (Kalb et al., 2021) and diverse manifestations, including abnormal language development, social disorders, restricted interests, and repetitive behaviors. In recent years, the physical and mental health issues of children with ASD have received increased attention. Common challenges include anxiety, social difficulties, delayed motor coordination, and skills development.

Trampoline exercise, a rhythmic and dynamic activity, has been suggested as a promising intervention to address these challenges in children with ASD. Its physical, sensory, and playful elements align well with the therapeutic goals of enhancing motor coordination, reducing anxiety, and promoting engagement. However, research on the effects of trampoline exercise on anxiety, height/weight ratio, explosive power of the lower limbs, and balance ability in children with ASD is still relatively limited.

Previous studies have explored trampoline biomechanics in athletic populations. For example, Wang et al. (2024) studied the biomechanical characteristics of the lower limbs of trampoline athletes and analyzed the main factors influencing their vertical jump. Watkins et al. (2023) developed a physical model of the forward jump phase of the trampoline from an energy conversion perspective and explored the determinants of jump height. While informative, these studies are primarily performance-oriented. Understanding these mechanisms, however, provides insight into how trampoline exercise may enhance neuromuscular control and postural balance—core deficits in many children with ASD.

In contrast, ASD-specific studies highlight the importance of tailored interventions that improve both psychological and physical domains. For instance, Vasa et al. (2020) systematically examined the prevalence and management of anxiety in ASD. Similarly, Chaidi et al. (2020) and Calderoni (2023) have emphasized parental roles and gender differences in ASD development. These insights underscore the multifaceted challenges ASD children face and support the exploration of multi-benefit physical interventions like trampoline exercise.

This study aims to address the lack of research on the physiological and psychological effects of trampoline exercise on children with ASD, focusing on its effects on anxiety, height/weight ratio, lower limb explosive power, and balance ability. We

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hypothesized that children with ASD who participated in a two-week trampoline training program would show improvements in anxiety levels, leg strength, balance, and weight-to-height ratio compared to a CG. Given the relatively small number of relevant studies, conducting feasibility studies can help identify possible problems in the study design and provide a basis for future large-scale intervention studies.

2. Literature Review

Recent research has increasingly highlighted the potential of physical activity-based interventions for children with autism spectrum disorder (ASD), particularly in treating anxiety symptoms and motor skill deficits. Trampoline interventions have received attention for their ability to blend physical engagement, sensory stimulation, and social interaction into an enjoyable format. This pattern suggests a broader recognition of the role of structured physical activity in treating ASD.

Evidence suggests that exercise can significantly improve motor skills in children with ASD. According to a systematic review and meta-analysis by Wang et al. (2025), structured exercise interventions have positive effects on social, behavioral, and motor skills. Similarly, Atigh et al. (2017) noted that exercise synchronized with music made this population more likely to exercise. These findings support the value of incorporating structured, engaging, movement-based interventions into ASD treatment programs.However, the reviewed studies vary in their intervention types, intensity, and evaluation metrics, which complicates cross-comparison and weakens generalizability.

In addition to improvements in motor skills, trampoline interventions have been associated with reduced anxiety. Kerns et al. (2017) (2016) and Naveed et al. (2019) demonstrated that nonexpert-mediated interventions can be more effective in alleviating anxiety and promoting development.Despite these findings, many of the interventions lack long-term follow-up and rely heavily on caregiver reporting, which may introduce bias. These studies suggest that sports such as trampolines can address both motor and psychological issues.

Sports interventions can also help children with autism with sensory and social engagement. This is a significant issue faced by children with autism. According to Hildebrandt et al. (2016), sports-based therapies can promote social interaction. On the other hand, Hariri et al. (2022) noted that this intervention can enhance sensory processing and behavioral regulation. Nevertheless, the mechanisms by which trampoline activities improve sensory integration remain underexplored.Therefore, trampoline sports' fun and interactive nature may help develop social and emotional management skills.

In addition, the acceptability and feasibility of these interventions must be considered. According to Woo et al. (2015) and Gupta et al. (2015), children showed higher compliance and engagement when participating in fun and dynamic activities such as trampoline sports. Therefore, interventions should be consistent with children's preferences to maintain motivation and reduce dropout rates.

However, Kerns et al. (2016) noted that early interventions produce better results, so individualized treatment plans must be developed based on age, symptom severity, and comorbidities.

In summary, although trampoline interventions are a promising approach to address motor, psychological, and social issues in children with ASD, further research is needed to improve intervention parameters, extend follow-up, and incorporate objective outcome measures. A more uniform evaluation framework would also facilitate comparison of study results and strengthen the evidence for integrating trampoline activities into comprehensive ASD management.

3. Materials and Methods

3.1. Study design

This paper is a blind, randomized, controlled feasibility study. It was conducted at a special education rehabilitation center in Shandong Province, China, and focused on children with ASD. Eligible children were randomly assigned to either the intervention group or the CG.

3.2. Participants

The participants were aged 9 - 12 years. In the intervention group, 33% had mild autism, and 67% had moderate autism. In the CG, 50% had mild autism and 50% had moderate autism. In the intervention group, 83% were male and 17% were female. In the CG, all participants were male (Table 1). A total of 12 participants were randomly divided into the intervention group (n = 6) and the CG (n = 6) (Table 1). The inclusion criteria for participants were as follows: (i) a physician-confirmed ASD diagnosis; (ii) mild to moderate ASD; (iii) male or female aged 9 - 14 years; (iv) the ability to follow verbal instructions; (v) the ability to participate in 30-minute exercise sessions three times a week for 2 weeks. Participants were excluded if they had the following conditions: (i) neck or joint problems (such as cervical spine abnormalities, arthritis, recent surgery, or fractures); (ii) cardiovascular conditions or heart disorders; (iii) epilepsy or seizure disorders; (iv) a history of bleeding disorders; (v) exercise-induced asthma.

3.3. Trampoline exercise intervention

The intervention group received training sessions lasting 30 minutes thrice weekly for two weeks. Each session consisted of three parts: a 5-minute warm-up, a 20-minute core session, and a 5-minute cool-down (Table 2). The CG continued with their regular school activities. Both participants and their parents were instructed not to participate in other exercise programs during the study period.

Table 1 Characteristics of participants.

Characteristics		intervention group (n=6)	CG (n=6)
Age	Mean ± SD	10.17 ± 1.169	10.17 ± 1.169
	Range	9 - 12	9 - 12
Level	Mild, n (%)	2 (33%)	3 (50%)
	Moderate,n (%)	4 (67%)	3 (50%)
Gender	M, n (%)	5 (83%)	6 (100%)
	F, n (%)	1 (17%)	0
Height (cm)	Mean ± SD	126.67 ± 9.67	138.33 ± 5.32
	Range	115-143	130 - 145
Weight (kg)	Mean ± SD	32.68 ± 6.55	35.03 ± 3.70
	Range	22.20 - 41.60	30.5 - 40.2

Note: Values showed means ± standard deviation, (*) is statistically significant, was p-value < 0.05. Level: Levels of autism.

Table 2 Content of exercise.

	Session 1	Session 2	Session 3
Week 1	The warm-up includes jogging and joint movements to increase heart rate and prepare the body	Combine music with small jumps, simulated flights, squats, and kicks. Try to touch a hanging object with the head, gradually increasing the height.|Deep breathing and gentle self-massage of the arms and legs	Deep breathing and gentle self-massage of the arms and legs
Week 2	The warm-up includes jogging and joint movements to increase heart rate and prepare the body	Start with small jumps while standing, then progress to one-foot balancing and eyes-closed exercises. Next, children work in pairs, throwing and catching balls to improve coordination.	Deep breathing and gentle self-massage of the arms and legs

3.4. Outcome measurements

Outcome measures were evaluated at baseline (before randomization) and after 2 weeks of training to assess the immediate effects. Anxiety was the primary outcome measure, while weight-for-height percentage, lower explosive power, and balance were secondary outcome measures. The principal investigator obtained permission from the original authors of the SCARED (Chen, 2012) via official email to use the scale in this study.

3.5. Anxiety

The revised Chinese version by Chen (2012) was used to quantify children's anxiety. The SCARED scale was employed to evaluate the anxiety levels of the participants. Parents or caregivers completed the SCARED for the assessment, and anxiety levels were determined according to the specific scoring procedure in the manual. HRV, a valuable tool for assessing anxiety in children with autism, provides a real-time, non-invasive measure of autonomic function. Given its ability to reflect changes in sympathetic and parasympathetic balance, it is instrumental in both research and clinical settings for monitoring anxiety in the ASD population (Unwin et al., 2016). In this study, HRV was used to assess anxiety in children with ASD.

3.6. Lower explosive power

The standing long jump(SLJ) assessed lower explosive power. Each child stood behind a marked line with their feet slightly apart and parallel. They were asked to jump with their knees bent as much as possible. The distance from the line on the ground to the back of the foot was measured using a measuring tape. Each child performed three jumps, and the best result was recorded (Lourenço & Esteves, 2021).

3.7. Balance

The one-leg stance (OLS) was used to assess static balance. Participants were asked to balance on either their right or left leg for as long as they could. They were required to keep their hips and knees slightly flexed, their arms hanging down, and their eyes closed (Posch et al., 2019). Each participant performed the test three times, and the best result was selected.

3.8. Statistical analysis

All data were statistically analyzed using SPSS (version 26.0, SPSS IMB). The Shapiro-Wilk test was used to examine whether all variables belonged to a normal distribution. After inspection, the data do not conform to the normal distribution,and the sample size is small (n=12) and the data do not conform to the normal distribution.

Specifically, the Wilcoxon signed-rank test was used to analyze the intra-group differences before and after the intervention, and the Mann-Whitney U test was used to compare the differences between the intervention group and the control group.

Effect sizes are reported using Cliff's delta (|δ|), appropriate for nonparametric comparisons. Cliff's delta represents the probability that a value chosen randomly from one group will be the same as a value chosen randomly from the other group. |δ| < 0.147 (negligible), 0.147 ≤ |δ| < 0.33 (small), 0.33 ≤ |δ| < 0.474 (moderate), and |δ| ≥ 0.474 (large).

4. Results

4.1. Anxiety

After intervention, the mean value of the HRV intervention group increased from 43.56 to 53.13 (p-value =0.03). In SCARED, the intervention group's scores decreased, showing a significant difference (p-value= 0.03) from the CG (Table 3). The median change was -3 in the SCARED intervention group and 0 in the CG. Mann-Whitney U value was 8, and the p-value was 0.1. There was no significant difference between the two groups. The median was 3.54 in the HRV intervention group and -0.01 in the CG. Mann-Whitney U value was 0, and the p-value was 0.009, which was far less than 0.05, and there was a very significant difference between the two groups. Cliff's delta is -1, the degree of difference is great, and the HRV in the intervention group has significant changes (Table 4).

Table 3 Comparison of within-group differences before and after 2-week intervention.

Variable	Group	Before intervention (M ± SD)	After intervention (M ± SD)	PRE-MedianΔ (IQR)	POST-MedianΔ (IQR)	p-value	effect size	Z
SLJ (cm)	CG	89 ± 14.95	90.33 ± 14.08	87 (76, 104.5)	86.5 (80.5, 103.25)	0.40	0.34	-0.85
	IG	55.17 ± 19.33	69 ± 18.77	53 (43.75, 71)	68.5 (54.75, 80)	0.03	0.9	-2.20
HRV (RMSSD/MS)	CG	48.51 ± 3.19	48.36 ± 2.79	48.29 (46.33, 51.05)	48.79 (45.88, 50.5)	0.60	0.22	-0.53
	IG	43.56 ± 10.64	53.13 ± 7.09	41.35 (34.2, 55.94)	55.69 (44.56, 59.36)	0.03	0.9	-2.20
OLS (s)	CG	9.95 ± 1.59	10.83 ± 2.16	9.88 (8.51, 11.55)	10.45 (8.97, 13.25)	0.17	0.56	-1.36
	IG	8.57 ± 4.69	11.55 ± 5.49	7.03 (5.06, 12.59)	9.78 (7.04, 16.77)	0.03	0.9	-2.20
SCARED	CG	40.17 ± 2.32	39.83 ± 4.31	40.5 (37.75, 42.25)	40.5 (36, 43.5)	0.75	0.13	-0.32
	IG	36.5 ± 6.38	33.5 ± 6.29	37 (30.7, 42)	32 (29, 38.75)	0.03	0.9	-2.20
BMI	CG	18.25 ± 0.64	18.44 ± 0.72	18.14 (17.62, 18.95)	18.22 (17.9, 19.20)	0.08	0.73	-1.78
	IG	20.26 ± 2.87	20.15 ± 2.53	19.94 (18.48, 21.63)	19.63 (18.77, 21.32)	0.67	0.17	-0.41

Note: Values showed means ± standard deviation, (*) is statistically significant, was p-value < 0.05

4.2. Standing long jump (cm) (SLJ)

After the intervention, the mean value of the intervention group increased from 55.17cm to 69cm, and the p-value was 0.03, which was significantly (p-value = 0.03) improved (Table 3). The median of the intervention group was 16cm, and that of the CG was 3cm. Mann-Whitney U value was 3.5, and the p-value was 0.02, which was less than 0.05, indicating significant differences in the change of SLJ results between the two groups. Cliff's delta is -0.81, indicating that the degree of difference is large, and the improvement in the intervention group is more prominent (Table 4).

4.3. One-leg standing with eyes closed (OLS) (s)

In OLS, the median change was 2.75s in the intervention group and 1.01s in the CG. The Mann-Whitney U value was 2, and the two groups had a significant (p-value= 0.01) difference. Cliff's delta was -0.89, the difference was significant, and the standing time of the intervention group with eyes closed improved significantly (Table 4).

4.4. BMI

Regarding BMI, the median change was -0.19 in the intervention group and 0.25 in the CG-Mann-Whitney U value = 9. There was no significant difference (p-value = 0.154) in BMI changes between the two groups (Table 4).

The intervention improved the participants' motor performance and anxiety levels. In the HRV analysis, the intervention group had significantly higher anxiety-related scores than the control group after the intervention, as well as significantly higher anxiety-related scores on the SCARED scale. However, the changes in SCARED scores between the different groups were not statistically significant. In contrast, HRV measures showed significant differences, indicating decreased anxiety levels. The intervention group showed significant improvements in standing long jump and one-leg stand with eyes closed. Significant increases in lower limb explosive power and balance control were demonstrated with large effect sizes. Despite this, neither group had significant changes in body mass index (BMI), suggesting that the intervention did not affect body composition during the study period. These findings suggest that the interventions helped alleviate anxiety symptoms and improve motor performance while indicating limited effects on BMI.

Table 4 Comparison between the CG and the IG.

Mann-whitney U Variable (Δ = post-pre)	IG (n=6) MedianΔ (IQR)	CG (n=6) MedianΔ (IQR)	Mann-whitney U	p-value	cliff's delta	95% CI	Z
SLJ(cm)	16 (4.5,20.75)	3 (-.25,4.25)	3.5	0.02	-0.81	(-1.00, -0.38)	-2.34
HRV(RMSSD/MS)	3.54 (2.59,22.25)	-0.01 (-0.84,0.5)	0	0.009	-1	(-1.00, -0.66)	-2.89
OLS(s)	2.75 (2.194.02)	1.01 (0.04,2.03)	2	0.01	-0.89	(-1.00, -0.52)	-2.56
SCARED	-3 (-4.5,-1)	0 (-3.25,2.25)	8	0.1	-0.56	(-0.88, 0.08)	-1.62
BMI	-0.19 (-0.49,0.23)	0.25 (-0.02,0.37)	9	0.154	-0.5	(-0.86, 0.14)	-1.44

Note: 95% CI: 95% confidence interval.

5. Disucssion

This study designed and conducted a feasibility randomized controlled trial to explore the specific effects of a two-week trampoline exercise intervention on anxiety levels, lower limb explosive power, balance ability, and body composition in children with ASD. After rigorous research and analysis, this experiment yielded a series of significant results, providing new insights and a scientific basis for the rehabilitation treatment of children with ASD.

Judging from the improvement in anxiety levels, the test results showed gratifying changes. In the intervention group, the children's heart rate variability (HRV) significantly improved ($p = 0.009$) after statistical analysis. This result showed that the function of the autonomic nervous system was effectively regulated, and the activity of the parasympathetic nervous system was significantly improved (Neuhaus et al., 2016). At the same time, the children's anxiety levels were assessed using the SCARED scale, and the results showed a significant reduction ($p = 0.03$) in scale scores. In summary, trampoline exercise is likely to effectively alleviate anxiety symptoms in children with ASD by regulating autonomic nervous system function and enhancing parasympathetic nervous system activity. Furthermore, from a neurobiological perspective, the rhythmic jumping movements during trampoline exercise may promote the release of endorphins, which also provides further theoretical support for its anti-anxiety effect.

Significant improvements were also achieved in lower limb explosiveness and balance. The standing long jump test, which assessed lower limb explosive power, showed significant improvement ($p = 0.02$) in the intervention group (Witassek et al., 2018), and the one-legged standing test with eyes closed, which assessed balance, also showed a significant improvement($p = 0.01$). These significant changes are closely related to the unique biomechanical characteristics of trampoline exercise (Schöffl et al., 2021). The unique properties of the elastic surface of the trampoline can significantly improve the efficiency of eccentric-concentric contraction of the lower limb muscles, thereby effectively improving the explosive power of the lower limbs. At the same time, continuous stimulation of the vestibular system during trampoline exercise is very likely to improve the postural control ability of children with ASD, which is very consistent with the results of this study, which showed that balance ability was significantly improved. The BMI also increased, but the change was not statistically significant. This may be explained by the relatively short duration of the intervention. More extended studies may be needed to detect significant changes in body composition. A more extensive, long-term intervention study could shed light on the potential effects of trampoline exercise on body composition.

However, despite the positive results of this study, some limitations cannot be ignored. First, regarding sample selection, this study only included 12 children with mild to moderate ASD. The sample size was relatively small, and the scope was narrow, which may limit the generalizability of the research findings to some extent (Qian et al., 2020). In order to more comprehensively and accurately reflect the impact of a trampoline exercise intervention on children with ASD, future studies need to expand the sample size further and cover a broader spectrum of symptoms (Lord et al., 2020). Large-scale randomized controlled trials collaborating with multiple medical institutions or special education centers could improve research evidence. Second, from the perspective of intervention duration, this study only conducted a short-term intervention of two weeks. Although immediate effects could be observed, long-term benefits could not be evaluated. Therefore, future studies should design intervention programs lasting several months or longer to better understand the long-term effects of trampoline exercise intervention (Rogers & Vismara, 2008). Finally, this study focused primarily on anxiety levels, lower limb explosive power, and balance ability and did not assess social and cognitive functions, two fundamental areas of deficits in ASD (Polit & Beck, 2008).

In future studies, advanced technologies such as virtual reality can be combined to perform multidimensional assessments. In contrast, functional magnetic resonance imaging (fMRI) or near-infrared spectroscopy technology can be combined to reveal further the impact of trampoline exercise on the neuroplasticity of children with ASD (Patten, 2016) (Kasari et al., 2008). Based on the results of this study, trampoline training, as a non-pharmacological intervention, offers numerous advantages and can be used as a powerful complement to traditional behavioral therapy, particularly for children with ASD who have low tolerance for medication (Portney & Watkins, 2009). Furthermore, trampoline equipment is readily available and inherently fun, making it ideal for integration into home rehabilitation or school physical education classes. Training intensity must be precisely adjusted based on the child's motor abilities and symptom severity. For example, music or gamification elements can be used intelligently to further enhance children with ASD engagement and ensure maximum intervention effectiveness (Vasa et al., 2020).

This study preliminarily confirmed, through a rigorous randomized controlled feasibility trial, that short-term trampoline exercise intervention can effectively improve anxiety symptoms, lower limb motor function, and balance ability in children with ASD. Although the study has some limitations, its safety, playfulness, and ease of implementation make it a potential candidate for ASD rehabilitation intervention. In future studies, more rigorous research designs are needed to clarify further the mechanism of action and long-term benefits of trampoline exercise intervention, provide a more comprehensive and scientific basis for clinical practice, and better assist the rehabilitation and growth of children with ASD.

6. Conclusions

This study demonstrates the effectiveness of physical activity interventions, particularly those that incorporate sensory and motor elements, in improving anxiety symptoms and motor performance in children with ASD. Significant improvements in heart rate variability (HRV), standing, long jump, and balance suggest that these interventions can play an important role in addressing the psychological and physiological issues often experienced by children with ASD. Furthermore, the findings highlight that fun and accessible exercises such as trampolining can improve emotional well-being, motor performance, and engagement. However, longer-term or more targeted interventions are needed to change body composition, as there were no significant changes in body mass index (BMI). Future studies should further investigate the optimal intensity, long-term effects, and personalization of these interventions to ensure that they have a broader and more sustainable impact on the health and quality of life of children with ASD.

Ethical considerations

This study was conducted by the principles of the Declaration of Helsinki and was approved by the Ethics Committee of the Center for Ethics in Human Research in Khon Kaen University (No. HE672160).

Conflict of Interest

The authors declare no conflicts of interest.

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