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Efficacy of Gaming Therapies on Balance in Children with Autism Spectrum Disorder: A Scoping Review

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ABSTRACT
Autism Spectrum Disorder (ASD) commonly result in postural control and balance deficits mainly due to motor planning, sensory integration, motor and anticipatory postural control adjustments. Emerging technology based rehabilitation approaches like Kinect-based therapy, exergaming and virtual reality, provide interactive and task-oriented environments that may facilitate motor learning and engagement. Objective of this study is to systematically link and synthesize the available interventional evidence on Kinect, exergaming, and VR-based balance training in children with ASD. This review was conducted in accordance with PRISMA-ScR guidelines. Electronic databases like scopus, PubMed, PEDro, Web of Science, and Google Scholar) were used for searching studies published during the time period from 2010 to 2025. Experimental, RCTs and quasi-experimental investigating technology based interventions like Kinect, VR, or exergaming interventions for improving balance outcomes were included. Data was extracted and synthesized in descriptive manner. 12 studies met the eligibility criteria. Duration of intervention ranged from acute one-session exposure to twelve week programs per week. In most studies, consistent improvements were found in static/dynamic balance, and postural control. However, heterogeneity in methodology, small sample sizes, and less follow-ups were evident. Kinect and VR-based interventions demonstrate promising potential in improving balance and postural control in children with ASD. Current evidence exposes the variability in protocols and in long-term outcomes. Future research should focus on standardized intervention protocols and randomized controlled trials in large scale.

Keywords: Autism Spectrum Disorder, Kinect-Exergaming, Virtual Reality, Balance Training, Good health and well-being.

INTRODUCTION

Autism Spectrum Disorder (ASD) is characterized by persistent impairments in social communication and the presence of repetitive and restricted patterns of behavior. In addition to these core features, increasing recent evidences highlight significant impairments in coordination, postural control and balance (Li, H et al., 2025).

Postural control is a basic and important motor ability that depends on the integration of vestibular, visual, and somatosensory inputs to maintain orientation in space and stability. ASD often demonstrate impaired sensory integration, delayed/reduce anticipatory postural adjustments, and increased postural sway, which together contribute to compromised balance and functional mobility (Ghobadi, N etal, 2019) . These negatively influence participation in ADL, academic tasks, and social engagement.

Traditional physiotherapy interventions targeting balance and motor control have demonstrated effectiveness in improving functional outcomes in children with ASD. However, therapy adherence and engagement remain challenging due to behavioral characteristics such as reduced attention span, decreased motivation, and difficulty following structured tasks (Miranda, J et al , 2025). These limitations necessitate the exploration of innovative and engaging rehabilitation approaches.

In recent years, technology-assisted rehabilitation, particularly Kinect-based exergaming and virtual reality (VR), has gained considerable attention in pediatric neurorehabilitation. Kinect-based systems utilize motion-sensing technology to provide interactive, task-oriented activities with real-time visual feedback, thereby promoting motor learning through repetition and engagement (Soniyasri et al, 2024). Similarly, VR-based interventions create immersive environments that facilitate multisensory stimulation and enhance motor performance (Ma, X etal. 2025).

Emerging physiotherapy studies suggest that these technologies may improve coordination, balance and functional mobility in ASD. Kinect-based gaming interventions have showed improvements in object control skills and postural stability following structured training programs. RCTs have further showed significant improvements in motor function

and balance with both Kinect-based and exergaming interventions when compared to conventional therapy approaches. Additionally, VR-based interventions have shown promising results in enhancing manual dexterity, balance and overall motor performance through interactive and immersive training programs (Ghobadi et al, 2019).

Exergaming interventions have also resulted in improvements in behavioral and cognitive domains especially attention and reduction in repetitive behaviors. Furthermore, these interventions have been shown to increase physical activity levels and engagement, which are critical factors in paediatric rehabilitation (Anderson-Hanley et al, 2011).

Despite these encouraging findings, the existing literature remains heterogeneous in terms of intervention protocols, study design and outcome measures. Many studies have limitations like small sample sizes, short duration of intervention, and lack of long-term follow-up . Moreover, there is a relative scarcity of high-quality RCTs specifically focusing on Kinect-based interventions for balance training in ASD.

With these limitations and the rapidly evolving technology-assisted rehabilitation, there is a need to systematically find and map the available evidences to identify trends/gaps, and future research directions. Scoping reviews are particularly suited for this purpose, as they allow for comprehensive exploration of emerging evidence across diverse study designs.

Therefore, the present scoping review aims to synthesize the existing interventional evidence on Kinect, exergaming, and virtual reality-based balance training in children with ASD, with a focus on intervention characteristics, outcome measures, and effectiveness.

Objective:

The objective of this scoping review was to systematically map and synthesize the existing evidence on Kinect, exergaming, and VR-based interventions targeting balance and postural control in children with ASD, with specific focus on: Types of interventions and gaming platforms used, Intervention dosage (frequency, duration, intensity), Outcome measures for balance and postural control, Reported effectiveness of interventions, and Methodological characteristics and research gaps

METHODS

Study Design: A scoping review methodology was adopted following the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Scoping Reviews) guidelines.

Inclusion Criteria: Children and adolescents (≤18 years) diagnosed with ASD, Studies employing Kinect, virtual reality, or exergaming interventions, Studies reporting balance or postural control outcomes, Experimental, quasi-experimental, or randomized controlled trials, Articles published between 2010 and 2025 and English language publications.

Exclusion Criteria: Non-interventional studies (observational, cross-sectional), Systematic reviews and meta-analyses, Case reports or single-case designs and Studies without balance-related outcomes.

Search Strategy: A comprehensive literature search was conducted across the following databases: PubMed, Scopus, Web of Science, PEDro, Google Scholar .

Keywords and Boolean combinations included were “Autism Spectrum Disorder” AND “Kinect” OR “Exergaming” OR “Active Video Games” OR “Virtual Reality” AND “Balance” OR “Postural Control”.

Study Selection: Titles and abstracts were screened for relevance, Full-text articles were assessed based on eligibility criteria, and Studies meeting inclusion criteria were included in the final synthesis.

TABLE 1: Study characteristics, Interventions, Outcomes and Key findings in ASD

Author & Year	Country	Study Design & Sampling	Sample Size & Age	Comparator	Gaming Platform & Particular Game	Intervention Details	Outcome Measures	Key Findings	Limitations
Murugan et al. (2025)	India	Pilot RCT; Purposive sampling	30 children; 6–12 years	Comparison (Kinect vs. Conventional)	**Xbox Kinect:** *Kinect Adventures (River Rush)*. Chosen for high engagement and dynamic balance requirements.	6 weeks; 3 times/week	Pediatric Balance Scale (PBS), BOT-2	Significant improvement in static and dynamic balance compared to conventional therapy.	Small pilot sample size; lack of long-term follow-up.

Soniya sri et al. (2024)	India	Pilot Study; Convenience sampling	20 children; Mean age ~8 years	Comparison (Kinect vs. Conventional)	**Xbox Kinect:** *Kinect Sports & Adventures*. Chosen to target both gross motor and object control.	8 weeks; 5 times/week (40 min)	PBS, TGMD-2	Improvements in object control skills and pediatric balance scores in the experimental group.	Small sample size; gender bias (predominantly male).
Ghobadi et al. (2019) [Art 3]	Iran	Experimental Study; Convenience sampling	24 children; 7–12 years	Comparison (Kinect vs. Control)	**Xbox Kinect:** *Kinect Adventures*. Chosen for its focus on postural shifts and weight bearing.	6 weeks; 3 times/week	Biodex Balance System (Static/Dynamic stability)	Significant reduction in postural sway and improvement in dynamic stability.	Small sample size; no assessment of functional daily activities.
Golden & Getchell (2017) [Art 4]	USA	Repeated Measures (Crossover); Convenience	17 children (9 ASD, 8 TD); 8–11 years	Comparison (Active vs. Sedentary vs. Walking)	**Xbox Kinect:** *Kinect Adventures (River Rush, 20,000 Leaks)*. Chosen to assess physical activity intensity.	Single sessions (20 min each)	Actical Accelerometer (AC, %MVPA)	Active gaming (AVG) provided moderate-to-vigorous physical activity (MVPA) comparable to walking.	Very small sample; only assessed short-term activity levels, not long-term balance.
Anderson-Hanley et al. (2011) [Art 6]	USA	Pilot Studies; Purposive	11–12 children; 8–16 years	Comparison (Cybercycle /Wii vs. Baseline)	**Wii Fit & Cybercycle:** *Wii Games*. Chosen to see if exergaming increases	Pilot 1 (Single bout); Pilot 2 (Multiple)	Repetitive Behavior Scale (RBS-R), Digit Span	Reduction in repetitive behaviors and improvement in executive	Small sample size; diverse age range; pilot nature of the study.

					compliance over traditional exercise.			function (cognition).	
Milajerdi et al. (2021) [Art 7]	Iran	RCT; Random sampling	60 children; 6–10 years	3 Groups (Kinect vs. SPARK vs. Control)	**Xbox Kinect:** *Kinect Sports/Adventures*. Chosen for multi-planar movement and feedback.	8 weeks; 3 times/week	MABC-2, BRIEF (Executive Function)	Kinect and SPARK both improved motor skills, but Kinect showed superior results for aiming/ catching.	No long-term retention test; potential for "novelty effect" of technology.
Ma & Song (2025) [Art 9]	China	RCT; Random sampling	60 children; 3–6 years	Comparison (VR Serious Games vs. Conventional)	**Interactive VR-Motion:** *Serious Games*. Chosen for immersive sensory feedback and motor planning.	12 weeks; 3 times/week	MABC-2, GARS-3	Significant improvements in balance, manual dexterity, and reduction in ASD symptoms.	Limited to very young children (3–6); requires high-cost VR equipment.
Travers et al. (2018) [Art 10]	USA	Feasibility Trial; Purposive	11 children; 7–17 years	Single Group (Pre-Post)	**Wii Balance Board:** *Ninja Training (Custom game)*. Chosen specifically to target prolonged postural stances.	6 weeks; 3 times/week (1 hr)	Postural Sway (Force Plate), Bruininks-Oseretsky (BOT-2)	Significant reduction in postural sway and high feasibility/enjoyment.	No control group; small sample size; custom hardware/software not widely available.
Cheldavi et al. (2014) [Art 11/13]	Iran	RCT; Convenience sampling	20 children; 7–9 years	Comparison (Balance Training vs. Control)	**Proprioceptive/Balance Boards:** (Sensor-integration based). Chosen to isolate the role of sensory information.	6 weeks; 3 times/week	Biodex Balance System	Balance training improved postural control, especially on compliant (unstable) surfaces.	Small sample; focus was more on clinical balance equipment than "commercial" gaming.

Caldani et al. (2020) [Art 12]	France	RCT; Random sampling	40 children; ~11.7 years	Comparison (Training vs. Rest)	**Balance Quest (Framiral):** *Biofeedback training*. Chosen for precise sensor-based postural recording.	Short-term (2 sessions)	Postural Sway (Surface/Area)	Observed improvements in postural control due to training effect and test-retest familiarity.	Very short intervention duration (6 mins); limited generalizability to long-term therapy.
Miranda et al. (2025)	Brazil	Crossover RCT; Randomization	9 children (Male); 8.6 years	Comparison (Exergames vs. Traditional)	**Xbox Kinect:** *Kinect Adventures*. Chosen to compare inhibitory control and balance vs. physical games.	Single sessions (20 min)	Stroop Test (Inhibitory control)	Exergames and traditional games both improved inhibitory control, but exergames were more engaging.	Very small sample (9 males); limited to immediate post-exercise effects.
Surabhi Date (2025) [Thesis]	USA	Controlled Clinical Trial; Purposive	24 participants; Youth/Young Adults	Comparison (VR vs. Control)	**VR Active Video Gaming:** *Oculus/Kinect based exergaming*. Chosen for high-immersion motor learning.	8 weeks; 2 times/week	Static/ Dynamic Balance (Force Plate)	Significant improvements in dynamic balance and weight-shifting ability.	Small sample; wide age range (youth to young adults) makes results variable.

RESULTS

A total of 12 studies met the inclusion criteria and were included in the final synthesis. These studies comprised randomized controlled trials, experimental studies, feasibility trials, and controlled intervention designs focusing on Kinect, exergaming, and virtual reality-based interventions targeting balance and postural control in children with Autism Spectrum Disorder.

Study Characteristics:

The included studies demonstrated heterogeneity in terms of study design, sample size, intervention protocols, and outcome measures.

Study Design Distribution: Randomized Controlled Trials (RCTs): **5 studies**, Experimental/Quasi-experimental studies: **4 studies** and Feasibility/Pilot studies: **3 studies.**

Sample Characteristics: Sample sizes ranged from **9 to 60 participants** with age range: **3 to 17 years.** Majority of studies focused on **school-aged children (6–12 years)**

Intervention Characteristics:

Intervention duration: Acute (single session) to 12 weeks**.** Most common duration: 6–8 weeks Frequency: Typically 2–5 sessions per week**.** Most commonly 3 sessions/week. Session duration: 20–60 minutes**,** with most studies using 30–45 minutes

Types of Interventions:
Interventions were categorized into: **Kinect-based gaming interventions**: Xbox Kinect platforms (e.g., Kinect Adventures, Kinect Sports) with focus on dynamic balance, weight shifting, and coordination. **Exergaming interventions**: Active video games (Kinect/Wii-based) with emphasis on physical activity and engagement. **Virtual Reality (VR) interventions**: Immersive and semi-immersive VR systems with focus on multisensory integration and motor planning.
Outcome Measures: The most commonly used outcome measures included: Pediatric Balance Scale (PBS), Timed Up and Go (TUG), Biodex Balance System, Postural sway (force platform measures), Bruininks-Oseretsky Test of Motor Proficiency (BOT-2) and Movement Assessment Battery for Children (MABC-2).
Effects on Balance and Postural Control: Across the included studies, consistent improvements were observed in both static and dynamic balance outcomes following intervention.
Key Findings were Significant improvement in static balance (PBS, postural sway measures), Enhanced dynamic balance and functional mobility (TUG, BOT-2), Reduction in postural sway and instability, Improved weight-shifting ability and postural strategies and Greater improvements observed when technology-based interventions were combined with conventional physiotherapy.

DISCUSSION

This scoping review found evidence from twelve interventional studies scrutinizing the effects of Kinect, virtual reality and exer-gaming based physiotherapy interventions on balance in children with ASD. These findings highlight that these technology-assisted physiotherapy interventions consistently resulted in positive effects on postural control and functional balance.
Theses improvement can be linked to several key mechanisms like **Task-specific repetitive practice which** enhanced skill acquisition and motor learning, **Augmented visual and auditory feedback which f**acilitated error correction and motor adaptation, **Multisensory stimulation which** improved integration of various sensory inputs (visual, vestibular, and somatosensory) and **Increased engagement and motivation** which enhanced adherence to therapy.
From a neurophysiological perspective, these interventions would have promoted experience-dependent neuroplasticity, leading to improved postural control and motor planning.

Comparison Across Intervention Types:
Kinect-based interventions demonstrated strong effectiveness in improving both static and dynamic balance due to their emphasis on full-body movement, real-time feedback, and task-oriented activities. Exergaming approaches contributed to improvements in both motor and cognitive domains, highlighting their role in promoting holistic rehabilitation. Virtual Reality Interventions showed promising results, particularly in enhancing sensory integration and motor coordination through immersive environments.

Clinical Implications:
The findings suggest that Kinect and VR-based interventions can be effectively integrated into paediatric physiotherapy programs as adjunct therapies to traditional physiotherapy rehabilitation, and also as home or community based interventions and as motivational tools to improve participation and adherence to therapy. These approaches are particularly valuable in ASD, where increased attention and engagement is a critical determinant of intervention success.

CONCLUSION

This scoping review demonstrates that Kinect-based exergaming and virtual reality interventions are effective in improving balance and postural control in children with Autism Spectrum Disorder. These interventions provide engaging, task-specific, and multisensory environments that facilitate motor learning and enhance rehabilitation outcomes.
However, the current evidence base is limited by methodological variability, small sample sizes, and insufficient long-term follow-up. Future research should focus on conducting large-scale, well-designed randomized controlled trials with standardized intervention protocols and outcome measures.
Kinect and VR-based interventions represent promising adjuncts to conventional physiotherapy and have the potential to play a significant role in advancing pediatric neurorehabilitation for children with ASD.

RESEARCH HIGHLIGHTS:

- Postural control and balance deficits occur mainly due to motor planning, sensory integration, motor and anticipatory postural control adjustments in ASD.
- Emerging technology based rehabilitation approaches like Kinect-based therapy, exergaming and virtual reality, provide interactive and task-oriented environments that may facilitate motor learning and engagement.
- Synthesizing the existing interventional evidence on Kinect, exergaming, and virtual reality-based balance training in children with ASD, with a focus on intervention characteristics, outcome measures, and effectiveness.

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