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Exploring Active Gaming with Xbox Kinect as a Balance Intervention for Children with Autism Spectrum Disorder: Pilot Randomized Controlled Trial

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Abstract: Postural instability and motor deficits are frequently observed in children with autism spectrum disorder largely due to atypical sensory integration and poor motor planning. These difficulties usually make it difficult for them to perform everyday duties endanger their independence and negatively affect their overall quality of life. Though they can sometimes lack originality and may not sustain long-term interest traditional therapeutic approaches can enhance motor function and balance. Conversely interactive and entertaining active video games (AVGs) such as those played with an Xbox Kinect combine therapeutic effectiveness with enjoyment and active engagement.

- ***Aim***

To assess the feasibility and early effectiveness of Xbox Kinect based active video game interventions in enhancing balance among children with autism spectrum disorder.

- ***Materials and Methods***

This pilot RCT involved 30 children with ASD (6–12 years), randomized to an intervention group (Xbox Kinect + physiotherapy, n = 15) or control group (physiotherapy alone n = 15). Training was delivered thrice weekly for 8 weeks. Feasibility was assessed through adherence safety and acceptability while preliminary outcomes included the Paediatric Balance Scale (PBS) and Timed Up and Go (TUG) test.

- ***Results***

Recruitment and retention were excellent with all participants completing the study (100%). No adverse events occurred supporting the intervention's feasibility. Compared with the control group, the intervention group demonstrated significant gains in PBS ($p < 0.001$) and TUG ($p < 0.001$).

- ***Conclusion***

This pilot trial suggests Xbox Kinect–based training is safe, feasible and acceptable for children with ASD with preliminary evidence of balance benefits larger RCTs are needed to confirm efficacy and long-term outcomes.

Keywords: *Autism Spectrum Disorder, Balance, Xbox Kinect, Pediatric Physiotherapy, Pilot Study*.

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I. INTRODUCTION

The neurodevelopmental condition known as autism spectrum disorder (ASD) is characterized by limited or repetitive behavioral patterns as well as persistent challenges with social communication and interaction. [1]. Beyond these core features many children with ASD exhibit significant motor impairments including difficulties with coordination, balance and postural control [2]. These deficits may limit their ability to participate in daily activities restrict engagement in play and physical exercise and contribute to social isolation [3]. Although motor difficulties in children with ASD are frequently overshadowed by cognitive and behavioral issues increasing evidence indicates that these challenges significantly influence overall functional independence and quality of life [4].

Balance control is a fundamental motor skill that underpins many aspects of childhood development such as walking, running, climbing and participating in sports [5]. Children with ASD often exhibit poor postural control atypical gait patterns and reduced integration of sensory inputs from the visual vestibular and proprioceptive systems. [6]. These impairments not only compromise physical performance but also exacerbate social and emotional difficulties as children may avoid group activities that challenge their motor skills [7]. Enhancing balance in children with ASD is therefore an important therapeutic goal as it directly impacts both functional mobility and psychosocial participation [8].

Traditional therapeutic approaches for improving motor skills in ASD include physiotherapy occupational therapy, sensory integration and structured exercise programs [9,10]. While these interventions have shown benefits maintaining long-term adherence can be difficult particularly because many children with ASD demonstrate limited motivation for repetitive non-engaging tasks [11]. Therapies that lack interactive or playful elements may not sustain their interest reducing effectiveness. This has prompted researchers and clinicians to explore novel engaging and technology based interventions that can capture attention and encourage active participation while delivering therapeutic benefits.

Active video games or exergames, offer a promising alternative intervention [12]. Unlike conventional sedentary video games AVG require physical movement using motion-sensing technology to track body movements and translate them into in-game actions [13]. The Xbox Kinect system in particular has emerged as a widely accessible platform that enables full-body interaction without the need for handheld controllers [14]. Through a camera and depth sensor Kinect captures the player's gestures and translates them into real-time game responses, creating an immersive and interactive environment [15]. Such games often involve activities that challenge balance coordination reaction time and motor planning making them potentially suitable for therapeutic use in children with developmental disorders [16].

For children with ASD Xbox Kinect-based AVGs may offer several advantages [17]. First the gamified nature of the intervention enhances motivation and enjoyment increasing adherence compared to traditional exercise. Second, the immediate visual and auditory feedback provided by the system supports learning through reinforcement a mechanism particularly beneficial for children with ASD who often respond well to structured feedback. Third, the home-based feasibility of Kinect allows for flexible implementation in both clinical and domestic settings potentially reducing therapy costs and expanding access to intervention. Importantly, Kinect games can be designed or selected to emphasize balance-related activities such as shifting weight maintaining postural alignment or responding to dynamic balance challenges [18,19].

Earlier research has investigated the application of exergames for individuals with motor impairments including children with cerebral palsy, Down syndrome and developmental coordination disorder. Findings suggest improvements in balance mobility and engagement supporting the potential of AVGs as adjunctive therapy [20]. However, research focusing specifically on children with ASD remains limited. A few pilot trials have reported that Kinect-based interventions can improve motor skills attention and social participation but evidence regarding their impact on balance is still emerging [21]. There are also few well designed randomized controlled trials in this area and the methodological flaws in previous research such as small sample sizes and the lack of standardized outcome measures highlight the need for more investigation.

A pilot randomized controlled trial is particularly suitable for addressing this knowledge gap. Pilot studies serve as preliminary investigations that evaluate feasibility refine protocols and generate data for larger-scale trials. In the context of Xbox Kinect interventions for children with ASD, a pilot study can offer valuable information on recruitment feasibility, participant adherence, safety and the suitability of balance assessment tools. It can also provide initial evidence of effectiveness informing the design of larger, more conclusive trials.

This study looks at how active video game training with an Xbox Kinect affects balance in kids with ASD. By comparing an intervention group receiving structured AVG sessions with a control group undergoing conventional therapy this pilot trial seeks to determine whether Kinect training can produce measurable improvements in postural stability. The study also explores the feasibility of integrating such technology into pediatric rehabilitation programs for ASD. The results of this trial may have significant ramifications for clinical practice and the development of novel therapeutic approaches given the growing accessibility of gaming technologies and the demand for captivating child-centered interventions.

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II. MATERIALS AND METHODS

To investigate how Xbox Kinect-based active video game (AVG) training affects balance in kids with autism spectrum disorder a pilot randomized controlled trial (RCT) was carried out in accordance with CONSORT guidelines for feasibility and pilot studies. Random assignment was used to place participants in the intervention group which received AVG training or the control group which received conventional physiotherapy. A neutral administrator who was not involved in the delivery of the intervention or the administration of the tests disclosed the group assignments which had been hidden in opaque sealed envelopes. A computer-generated sequence in a 1:1 ratio was used for randomization. The eight-week intervention was planned.

The study was officially approved on 02/030/2024/ISRB/PGSR/SCPT by the Saveetha College of Physiotherapy's Institutional Scientific Review Board which is part of the Saveetha Institute of Medical and Technical Sciences in India. In compliance with the Declaration of Helsinki the study was carried out.

➢ *Inclusion Criteria*

Participants children aged 6 to 12 years with a confirmed diagnosis of autism spectrum disorder recruited from pediatric rehabilitation centers and special education schools. The diagnosis of ASD was verified by a pediatric neurologist or developmental pediatrician based on DSM-5 criteria. Eligible children were required to be able to follow simple verbal instructions and stand and walk independently for a minimum distance of 10 meters.

➢ *Exclusion Criteria*

Exclusion criteria included the presence of coexisting neurological or orthopaedic conditions such as cerebral palsy or muscular dystrophy severe visual or auditory impairments, uncontrolled seizures and prior participation in structured balance training within the past six months.

➢ *Sample Size Calculation*

G*Power version 3.1.9.7 was used for a post hoc power analysis to determine the independent samples t-tests attained power. The analysis used a two-tailed test with a medium effect size (d = 0. 5) a significance level of α = 0. 05 and sample sizes of 10 for the experimental and control groups.

❖ *Study Procedure*

➢ *Intervention Group (Xbox Kinect AVG Training)*

Children in the intervention group underwent structured Xbox Kinect-based active video game training sessions.Frequency: 3 sessions per weekDuration: 30 minutes per sessionProgram Length: 8 weeksGames Selected: Kinect Sports (Bowling, Soccer, Athletics), Kinect Adventures (River Rush, Reflex Ridge) and Dance Central chosen for their emphasis on weight shifting, postural adjustments, dynamic balance and whole-body movements.Sessions were delivered in a quiet therapy room under therapist supervision.Each training session commenced with a five minute warm-up and concluded with a five-minute cool-down.. During training, children were encouraged to perform game-related movements such as side-stepping, squatting, jumping and reaching. Therapists provided verbal cues and physical assistance as needed to ensure safety.

➢ *Control Group (Conventional Therapy)*

The control group underwent conventional physiotherapy targeting balance and postural control. Sessions were conducted three times per week, each lasting 30 minutes, over an 8-week period. The program incorporated static balance exercises such as single-leg stance and tandem standing, dynamic balance activities including line walking and heel-to-toe walking as well as coordination tasks like ball throwing and catching.

➢ *Outcome Measures*

Primary outcomes were static and dynamic balance, assessed pre- and post-intervention.

- Pediatric Balance Scale (PBS): A 14-item assessment derived from the Berg Balance Scale, designed specifically for children evaluating balance during sitting, standing and transitional movements. Scores range from 0 to 56 with higher scores reflecting superior balance abilities.
- Timed Up and Go (TUG) Test: Assesses dynamic balance and functional mobility. Children are asked to stand from a chair, walk three meters, turn around return to the chair and sit down with the total time required being recorded.

Secondary measures included session attendance dropout rate and observed engagement/motivation levels.

III. STATISTICAL ANALYSIS

SPSS version 24 used for data analysis. The data sets normality was evaluated using the Shapiro-Wilk test. Mean ± standard deviation used to report descriptive statistics. Comparisons between groups (intervention vs independent t-tests for normally distributed variables or Mann-Whitney U tests for non-normal distributions were used for the control. Where appropriate Wilcoxon signed rank tests or paired t-tests were used to assess within-group differences before and after the intervention. Statistical significance was defined as a p-value of less than 0. 05.

IV. RESULTS

The 8-week intervention and assessments were completed by all 30 enrolled children (15 in each group), resulting in a 100% retention rate. There were no reported negative outcomes or safety issues, indicating that the Xbox Kinect training was both practical and well-received by participants.

➢ *Pediatric Balance Scale:*

Following the intervention experimental group demonstrated a significant increase in mean PBS scores rising from 28.7 ± 4.5 at baseline to 35.1 ± 5.0 ($t = 4.21$, $p = 0.0007$), indicating notable improvements in postural stability after Kinect-based video game training. In the control group, PBS

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scores changed from 18.5 ± 3.2 to 14.2 ± 2.8 (t = –3.29, p = 0.001). Although this improvement was statistically significant, it was markedly smaller compared to the gains observed in the experimental group.(Table 1, Graph 1).

➢ *Timed Up and Go:*

Functional mobility showed improvement in both groups. In the experimental group mean TUG time decreased significantly from 12.61 ± 1.40 seconds at baseline to 10.57 ± 1.32 seconds post-intervention (t = –2.04, p = 0.001). The control group demonstrated a smaller improvement with TUG times decreasing from 12.18 ± 1.62 seconds to 11.58 ± 1.57 seconds (t = –0.64, p = 0.001). (Table 2, Graph 2).

➢ *Between-Group Comparisons (Post-Test)*

Post-intervention comparisons demonstrated the greater effectiveness of the experimental intervention. For balance measured by the PBS the experimental group attained a higher mean score of 19.6 ± 2.1 compared to 18.3 ± 2.07 in the control group with the difference reaching statistical significance (t = 7.030; p = 0.001).

- *Mobility (TUG)*

Kinect training also produced faster TUG times (19.2 ± 7.26 seconds) relative to the control group (13.5 ± 2.21 seconds) with the difference reaching significance (t = 2.744; p = 0.0133) (Table 3, Graph 3).

Children receiving Xbox Kinect based video game training demonstrated substantial gains in both static/dynamic balance and functional mobility compared with peers who continued with conventional physiotherapy alone. Improvements were not only statistically significant within the experimental group but also superior to standard care at post test. These results offer initial support for the use of Kinect-based exergames as an engaging and effective supplementary tool in pediatric physiotherapy for children with ASD.

V. DISCUSSION

This study looked into how active video game training with an Xbox Kinect affected the balance and mobility of kids with autism spectrum disorder. The intervention group outperformed the control group after the intervention showing notable improvements on the Timed Up and Go (TUG) test and the Pediatric Balance Scale (PBS). These results demonstrate how interactive video games may be used as a supplemental therapy in pediatric neurorehabilitation.

Children with autism spectrum disorder (ASD) often have balance issues which are mostly linked to issues with postural control motor coordination and sensory integration. [22]. Traditional therapeutic interventions focus on structured motor training and physiotherapy to enhance functional mobility. However the use of active video games offers an engaging and motivating platform that combines task-specific training with real-time feedback. In this study, Xbox Kinect training allowed children to practice dynamic balance tasks in an immersive and enjoyable environment likely contributing to higher engagement and improved outcomes.

The intervention groups notable improvement in PBS scores is in line with earlier research showing that exergame-based interventions can successfully improve children with developmental disorders static and dynamic balance.[23,24]. Similarly, the reduction in TUG times suggests better functional mobility and motor planning which are critical for daily activities such as walking, turning, and transitioning from one position to another. These outcomes may be explained by the repetitive practice of goal-oriented tasks embedded within video game play which enhances neuroplasticity and motor learning [25,26].

The experimental group exhibited more pronounced gains than the control group, underscoring the additional advantages of integrating technology-driven interventions. The control group showed only modest reductions in TUG times consistent with the limited effects of routine therapy alone. This supports the notion that novel interactive and motivational training modalities may enhance adherence and accelerate functional gains [27].

Another important aspect of active video game training is the promotion of visual-motor integration and proprioceptive awareness which are often compromised in children with ASD [28]. The Kinect system requires children to perform whole-body movements encouraging multisensory engagement and coordination. This multimodal stimulation may strengthen sensorimotor pathways and facilitate functional carryover into daily activities [29].

Although the results are promising it is important to acknowledge certain limitations. The short intervention period and small sample size limit generalizability and make it impossible to evaluate the long-term retention of mobility and balance improvements. To assess sustainability future research should use bigger randomized controlled trials with longer follow-up. Including extra metrics like gait analysis and quality of life evaluations could also provide a more thorough understanding of the efficacy of the intervention.

Overall the present findings are consistent with emerging literature that supports the integration of digital rehabilitation tools in pediatric populations. Xbox Kinect training can complement traditional physiotherapy by providing an interactive enjoyable and motivating environment which may increase participation and adherence.

VI. LIMITATIONS

This study is limited by its small sample size which affects the generalizability of the findings and the short intervention period of eight weeks which does not allow for assessment of long-term effects. The lack of participant therapist blinding and the novelty of Xbox Kinect may have introduced performance bias. Outcome measures were limited to PBS and TUG, leaving out broader domains such as quality of life and social participation. Finally, the program was tested only in a controlled clinical setting so its feasibility in home-based environments remains uncertain.

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VII. CONCLUSION

It has been discovered that active video game training with an Xbox Kinect can help children with ASD become more balanced and functionally mobile. Children in the experimental group showed higher improvements on the Timed Up and Go test and the Pediatric Balance Scale when compared to conventional therapy. According to these findings active video game interventions could be a useful addition to pediatric rehabilitation especially for kids with neurodevelopmental disorders. Larger sample sizes and longer follow up are needed for future research to prove clinical applicability and long term efficacy.

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- *Conflicts of Interest*

The authors confirm that there are no conflicts of interest associated with the publication of this study.

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