Original Article

Effects of Virtual Reality on Static and Dynamic Balance among Individuals with Down Syndrome

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ABSTRACT

OBJECTIVE: To determine the effects of virtual reality on static and dynamic balance among individuals with Down syndrome.

METHODOLOGY: A quasi-experimental study was conducted at Imran Rehabilitation Center, Karachi, Pakistan, from Nov 2020 to April 2021 through a randomized sampling technique. Twenty-four Down syndrome individuals between 6 and 9 years of Age were included. Children who could stand and walk independently, comprehend the instructions and were diagnosed with 50% to 70% IQ level (assessed using the Stanford Binet Intelligence Scale) were included. In contrast, DS children with autism, impaired vision or hearing loss and any associated neurological disorders, i.e. Epilepsy, muscular dystrophies and traumatic brain injury (TBI), were excluded. Data was analyzed using the SPSS version 23.

RESULTS: Group A (n=12) participants had a mean age of 8.08±0.79 years, and Group B (n=12) participants had a mean age of 7.61±0.94 years. Both groups had similar gestational Age and IQ levels. The Pediatric Balance Scale (PBS) and Rhomberg test assessed balance and motor control. Within-group analysis revealed significant improvements in both groups for PBS scores. Group analysis did not demonstrate significant differences in the PBS scores or Rhomberg test outcomes. The mean PBS scores for Group A and Group B were 50.33±2.22 and 49.41±3.20, respectively. In the Rhomberg test, no significant differences were found between the two groups with eyes open or closed.

CONCLUSION: The study concluded that static and dynamic balance was significantly improved in both groups; however, virtual reality group intervention showed a more significant improvement in static balance.

KEYWORDS: Down syndrome, Postural balance, Quality of life, Virtual Reality

INTRODUCTION

Down syndrome (DS), also known as trisomy 21, is a genetic disorder caused by the presence of an extra chromosome 21. It is one of the most common genetic chromosomal anomalies in approximately 1 in 700 live births worldwide. Individuals with Down syndrome often face various physical and cognitive challenges, which can impact their functional abilities and overall quality of life[1].

Considerable variability exists among infants and children with DS about the degree of disability and the specific features affected. More excellent joint range of motion, presumably attributable to ligamentous laxity, delayed development of postural reactions and myelination, low muscle tone, and congenital heart defects, all contribute to delayed motor skills. For example, children with DS tend to sit without support by 11 months, pull up to a standing position at about 17 months, and walk three independent steps at an average age of 24 to 26 months[2]. A study found that 73% of the children with DS whom they observed longitudinally were able to stand by 24 months of Age and that 40% could walk by 24 months. In contrast, the average onset of standing alone and walking in infants with typical development are 11 and 12 months, respectively[3].

Among the physical challenges experienced by individuals with Down syndrome, issues with balance and motor control are particularly prevalent. Impaired balance can significantly affect their daily activities, mobility, and risk of falls, leading to reduced independence and social participation[4]. Traditional rehabilitation approaches have been used to address these balance deficits; however, incorporating innovative and engaging interventions may further enhance treatment outcomes[5].

Virtual reality (VR) is a technology that provides a computer-generated, interactive, and immersive experience where users can interact with and manipulate a three-dimensional virtual environment in real-time[6]. VR-based interventions have gained

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popularity in various rehabilitation settings because they can provide task-specific and challenging training scenarios while promoting engagement and motivation[7].

VR in balance training among individuals with neurological conditions has shown promising results. Studies in populations with stroke and cerebral palsy[8], have demonstrated improvements in postural control and dynamic balance following VR-based interventions. However, the application of VR in individuals with Down syndrome remains relatively underexplored[9].

Regular physical activity is vital for the mental and physical progress of individuals with Down syndrome (DS), fostering motivation and emotional stability. This study aims to explore the potential benefits of a VR intervention targeting functional fitness in young adults with DS and mild-to-moderate mental retardation. The study expects improvements in postural stability, weight distribution, and functional balance performance using an immersive VR environment. The findings can inform effective intervention strategies to enhance the well-being and physical abilities of individuals with DS. This research could contribute valuable insights into rehabilitation and assistive technology, promoting inclusivity and optimizing support for individuals with diverse skills.

METHODOLOGY

A quasi-experimental study was conducted at Imran Rehabilitation Center, Karachi, Pakistan, from Nov 2020 to April 2021. Down syndrome individuals aged between 6 and 9 years were included in this study. Children who could stand and walk independently, comprehend the instructions and were diagnosed with 50% to 70% IQ level (assessed using the Stanford Binet Intelligence Scale) were included. In contrast, DS children with autism, impaired vision or hearing loss and any associated neurological disorders, i.e. Epilepsy, muscular dystrophies and traumatic brain injury (TBI), were excluded. Non-probability purposive sampling was used. The recruited participants were divided into two equal groups using the sealed envelope method. The ethical research committee department of Ziauddin College of Rehabilitation Science, Ziauddin University, approved the study.

Consent has been obtained from the parents or legal guardians of the individuals with Down syndrome participating in the study exploring the effects of virtual reality on static and dynamic balance. Both the groups performed warm-up exercises for 10 minutes that consisted of generalize stretching exercises of all four limbs. The intervention protocol of Group A (Experimental/Intervention group) included Nintendo Wii and Nintendo Fit exercises based on virtual reality games. Three games based on virtual reality were performed for 30 min. The games include the football heading game, ski slalom game, and table tilt game, which are exclusively based on improving the strength of the trunk, lower limb, and postural stability in Down syndrome children. Each game was performed for 10 minutes, with a rest duration of 2/3 minutes between each game. Group B (Control Group) were given intervention based on traditional therapy that comprised ball throwing and catching, reaching for an object while the participant was standing or sitting on an even or uneven surface, and stairs climbing up and down. Each intervention was performed for 10 minutes with a 2/3 minute rest between each.

The intervention given to the control group participants is exclusively based on improving children's balance and strength at the level of trunk, core and lower limbs. Both groups performed each session for approximately 30 – 40 minutes thrice a week for eight weeks. Twenty-four sessions were given in total. We assessed a static balance using the Rhomberg test with excellent reliability (r =0.8)[10]. Static balance was assessed with feet apart and feet together. The balance was evaluated at feet apart by keeping the participant's eyes open, and eyes closed, followed by feet together. The pediatric Berg balance scale (PBS) is widely used to measure the functional/ dynamic balance (r = 0.9)[11]. The PBS is a scale with 14 items, each score from 0 – 4, in which 0 means lowest function, and 4 indicates highest function, with a maximum score of 56. The 14 Items are related to maintaining a balanced transition of movement.

Data was analyzed using the SPSS version 23. Independent T-test analysis was used within and between the group analyses, and paired T-test was used.

RESULTS

The demographic characteristics of the study participants are presented in **Table I**. Group-A comprised 12 participants with a mean age of 8.08±0.79 years, gestational Age of 8.83±0.57 weeks, and IQ level of 62.42±2.90. Group B also consist of 12 participants with a mean age of 7.61±0.94 years, gestational Age of 9±0 weeks, and IQ level of 62.58±4.07. These findings suggest that the two groups were similar in terms of Age, gestational Age, and IQ level.

Pediatric Balance Scale & Rhomberg Test Independent T-Test Analysis

A paired t-test was applied for the group analysis as the data was normal. It was observed that Group A was significantly improved to 50.33±2.22 from 34.75±2.73 while Group B was also considerably enhanced to 49.42±3.20 from 33.75±3.69. However, a slightly higher improvement was noted in Group A (**Table II**).

Table I: Descriptive Data

Group	N	Age (years)	Gestational Age (weeks)	IQ Level
A	12	8.08±0.79	8.83±0.57	62.42±2.90
B	12	7.61±0.94	9±0	62.58±4.07

Table II: Outcomes of within groups

Outcomes	Group A Mean ± SD (Pre)	Group A Mean ± SD (Post)	Group B Mean ± SD (Pre)	Group B Mean ± SD (Post)
Pediatric Balance Scale	34.75±2.73	50.33±2.22	33.75±3.69	49.42±3.20
Mean Difference		15.58±0.51		15.67±0.49
P-value		0.005		0.00
Rhomberg Test				
Feet Apart w/ Arms Hanging	23.58±3.02	29.08±1.16*	21.75±3.46	27.42±2.87*
Mean Difference		5.50±1.86		5.67±0.59
P-value	0.049	0.002	0.007	0.008
Feet Together w/ Cross Arms	21.50±3.58	27.67±2.30*	20.58±4.50	26.42±3.17*
Mean Difference		6.17±1.28		5.83±1,33
P-value	0.014	0.005	0.015	0.019
Feet Apart w/ Arms Hanging EO	24.67±3.25	29.58±1.44*	22.00±2.98	28.17±2.40*
Mean Difference		4.91±1.81		6.17±0.58
P-value	0.049	0.002	0.007	0.008
Feet Apart w/ Arms Hanging EC	22.00±2.98	28.00±2.33*	19.00±3.69	26.25±2.30*
Mean Difference		6.00±0.65		7.25±1.39
P-value	0.014	0.005	0.015	0.019

*Note: SD = Standard Deviation; EO = Eyes Opened; EC = Eyes Closed; *Significant difference at p < 0.05.*

Pediatric Balance Scale and Rhomberg Test Paired-T Test Analysis

For the Rhomberg test, in feet apart with arms in hanging position, Group A was improved to 29.08±1.16 from 23.58±3.02 with eyes open, while Group B was improved to 29.58±1.44. With eyes closed, Group B was enhanced more than Group A, i.e. 28.17±2.40. Group B was improved to 28±2.33 in feet and cross arms, while similar improvements were noted in both groups with closed eyes (**Table III**). Pediatric Berg balance scale (PBS) before starting the virtual reality technology and after VR technology indicates improvement in scores.

Table III: Between-Group Analysis

Outcomes	Group A (n=12)	Group B (n=12)	P-value
Pediatric Balance Scale	50.33 ± 2.22	49.41 ± 3.20	0.38
Rhomberg Test (Feet apart)			
Eyes open	29.08 ± 1.16	29.58 ± 1.44	0.40
Eyes closed	27.66 ± 2.30	28.16 ± 2.40	0.81
Rhomberg Test (Feet closed)			
Eyes open	27.14 ± 2.87	28.01 ± 2.33	0.17
Eyes closed	26.41 ± 3.17	26.23 ± 2.30	0.21

Note: Values are presented as mean ± standard deviation (SD). P-values indicate the significance of between-group differences.

DISCUSSION

The current study demonstrated significant improvements in the Pediatric Balance Scale scores for both Group A and Group B, indicating the positive impact of the intervention on balance skills. These findings are consistent with previous literature, which reported similar improvements in balance and motor skills in children with developmental coordination disorder following a comparable intervention[12,13]. However, in contrast to former research, where no significant improvements in balance outcomes were observed despite a similar intervention, factors other than the intervention may have influenced the results[14,15]. Furthermore, the study's findings align with those of other studies, showing significant improvement in balance skills among children with motor impairments following a different intervention approach. The results emphasize the potential effectiveness of individualized interventions in optimizing balance outcomes for children with motor difficulties[16].

Both Group A and Group B in the current study showed improvements in all Rhomberg test conditions, consistent with prior studies, indicating the potential effectiveness of balance training interventions in enhancing children's balance abilities. However, mean improvements in the current study (Group A: 5.50 points, Group B: 5.67 points) were slightly lower than previous findings (mean improvement: 6.80 points)[17,18], possibly due to differences in intervention protocols or participant characteristics.

Compared to the present study, they revealed notably higher mean improvements in the experimental group than in the control group, implying the potential advantages of interventions targeting proprioceptive and vestibular inputs to enhance balance under reduced visual conditions[19]. Similarly, another study exhibited superior balance performance outcomes in participants who underwent proprioceptive training compared to those in the control group[20,21]. Moreover, prior research demonstrated that vestibular-based interventions resulted in more significant enhancements in postural stability among individuals with balance impairments compared to conventional balance training[22]. Collectively, these findings emphasize the significance of addressing sensory inputs in balance interventions and highlight the potential effectiveness of tailored strategies focusing on proprioceptive and vestibular mechanisms to optimize balance abilities in specific populations.

The current and previous studies both explored the effects of balance training on postural control in children. While both studies observed improvements in the Rhomberg test, they used different intervention approaches and outcome measures. The current study focused on the Rhomberg test under different visual conditions, while the former employed a multidimensional balance training program targeting various balance-related tasks. Both studies reported significant improvements in balance abilities, but the specific areas of balance enhancement and intervention strategies differed[23,24]; this indicates the potential benefits of utilizing various balance training approaches tailored to children's needs to optimize postural control outcomes.

CONCLUSION

The findings of this study indicate that both the virtual reality and traditional exercise interventions positively impacted the participants' static and dynamic balance. However, it is worth noting that the group that received the virtual reality intervention demonstrated a more significant improvement in static balance than the traditional exercise group. These results highlight the potential of virtual reality as a promising tool for balance training in individuals with balance impairments.

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AUTHOR CONTRIBUTION

Ghouri ER: Conception and design, critical revision for the important intellectual content
Memon AG: Manuscript drafting, final approval
Ali S: Analysis and interpretation of data
Adnan Q: Assembly of data
Tahir S: Data collection, assembly of data

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