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Effect of Virtual Reality on Trunk Control in Children with Developmental Delays

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Disclaimers

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ABSTRACT

Background: Developmental delays affect motor function and trunk control in children, impacting their overall development and daily activities. Virtual reality (VR) interventions have the potential to enhance motor abilities through engaging, personalized therapies.

Objective: This study aimed to determine the effectiveness of virtual reality-based neurodevelopmental treatment with trunk control exercises (VR-NDT-TCE) in improving trunk control and cognitive functions in children with developmental delays.

Methods: A single-blinded randomized controlled trial was conducted with 22 children aged 2-8 years diagnosed with developmental delays. Participants were randomly assigned to Group A (NDT-TCE) or Group B (VR-NDT-TCE) for a six-week intervention, three times per week. Trunk control was measured using the Trunk Control Measurement Scale (TCMS), and cognition was assessed through the Hammersmith Infant Neurological Examination (HINE) Performa. Data analysis was performed using SPSS version 27 with paired t-tests and Mann-Whitney tests.

Results: Significant improvements were observed in trunk control (TCMS score: 20.18 ± 2.40 in Group A vs. 24.18 ± 4.67 in Group B, $p = 0.017$). Group B showed notable gains in cognitive parameters, including conscious state ($p < 0.001$), emotional state ($p = 0.012$), and social orientation ($p = 0.031$).

Conclusion: VR-NDT-TCE significantly improved trunk control and cognitive outcomes, offering an effective intervention for children with developmental delays.

INTRODUCTION

Developmental delays in children are complex conditions that disrupt the normal trajectory of growth, particularly in motor, cognitive, language, and socio-emotional domains. The concept of "developmental delay" emerged prominently in mid-20th century research, reflecting the systematic study of child development and the identification of atypical progress in achieving key milestones. This ongoing developmental process, beginning at conception and continuing into adulthood, is influenced by a multitude of factors, including genetics, environment, nutrition, and chronic illnesses, which may result in delayed milestones. Such delays are typically assessed across various domains, including gross and fine motor skills, social interaction, and language acquisition, with significant delays in one or more areas often categorized as developmental delay (1). Globally, developmental delays affect a considerable proportion of children, with prevalence rates varying by region and socio-economic context. In low- and middle-income countries, the prevalence is notably high, with the World Health Organization estimating that approximately 10% of the global population has some form of disability. Developmental delays are estimated to affect between 10% to 15% of children, with variations seen across different regions and demographics (2).

Motor development, particularly trunk control, is crucial in early childhood as it underpins the ability to perform more complex motor tasks. Impaired trunk control, often observed in children with developmental delays and conditions like cerebral palsy, significantly hampers motor function, coordination, and stability, thus affecting daily activities and overall functional independence. Trunk control is foundational for children's motor development, enabling stabilization of the head and limbs, which is essential for achieving higher developmental milestones, such as stable hand movements and effective object manipulation. These abilities are intricately linked to cognitive skills and play opportunities, which further influence a child's overall development. However, children with developmental delays often exhibit slower and less coordinated trunk movements, leading to challenges in motor skill development, cognition, and daily functioning (3). Traditional interventions such as neurodevelopmental treatment (NDT), particularly the Bobath approach, have been widely used to enhance trunk control in children with such conditions. NDT focuses on improving postural control and muscle activation to support trunk stability. Despite its effectiveness, the limitations of conventional therapies highlight the need for innovative approaches that can engage children more effectively and cater to their individual needs.

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Recent advancements in virtual reality (VR) technology have introduced new possibilities in pediatric rehabilitation, offering personalized, immersive experiences that align with the principles of neuroplasticity. VR-based interventions provide real-time feedback and create engaging environments that motivate children to participate in repetitive, goal-directed activities, thereby enhancing motor learning and functional recovery. The integration of VR with traditional NDT techniques could potentially address the limitations of conventional therapy by providing a more stimulating and adaptive approach to rehabilitation. This study aims to investigate the effectiveness of a VR-based neurodevelopmental treatment on trunk control in children with developmental delays. The focus on trunk control is crucial, as it is a key determinant of gross motor function, balance, and overall motor coordination in children. Furthermore, the study seeks to explore the broader impact of VR interventions on cognitive and motor outcomes, considering the complex interplay between various developmental domains in children with delays (4).

Given the growing prevalence of developmental delays, particularly in regions with limited access to advanced therapeutic interventions, this study is poised to contribute valuable insights into the potential benefits of integrating VR into pediatric rehabilitation. The findings may have significant implications for enhancing practical approaches in regions like Pakistan, where traditional interventions are often underutilized, and innovative therapies like VR hold promise for improving the quality of care for children with developmental delays (5). By focusing on trunk control as a critical component of motor development, this study aims to fill a gap in the existing literature and provide a foundation for future research on the use of VR in pediatric rehabilitation. The outcomes of this study could lead to the development of more effective, child-centered therapeutic strategies that enhance motor function, cognition, and overall quality of life for children with developmental delays.

MATERIAL AND METHODS

This study utilized an experimental design with a single-blinded randomized clinical trial format to assess the effects of virtual reality-based neurodevelopmental treatment on trunk control in children with developmental delays. A total of 22 participants were included in the study, with the sample size determined using Epitool. Participants were randomly assigned to two groups, Group A and Group B, using a chit and draw method. Group A received traditional neurodevelopmental treatment-based trunk control exercises, while Group B underwent a virtual reality-based rehabilitation intervention combined with trunk control exercises based on the principles of handling and facilitation. The study was conducted at the Children Hospital & Institute of Child Health Care, Faisalabad, specifically within the Physical Therapy Department's outpatient setting.

Participants were recruited consecutively, meeting specific inclusion criteria: children aged 2-8 years, both male and female, diagnosed with developmental delays, and capable of following visual and verbal commands. Additionally, participants had to be classified within Gross Motor Function Classification System (GMFS) levels II, III, or IV and scored between 0 to 2 on the Modified Ashworth Scale. Exclusion criteria included children who were uncooperative, had visual or intellectual impairments, were using anti-epileptic or anti-spasticity medications, or had conditions such as quadriplegic, ataxic, athetoid, or mixed cerebral palsy. Children with severe mental abnormalities, cardiac anomalies affecting exercise tolerance, recent orthopedic surgeries (less than four months post-operation), use of botulinum toxin injections, bony malalignments, or contractures were also excluded. Parents were informed of their right to withdraw their child from the study at any time, and participants with gravitational insecurity were included as withdrawal criteria.

Ethical approval was obtained from the Ethical Review Committee of The University of Faisalabad before the commencement of data collection. The study was also registered on the Iranian Registry of Clinical Trials with the trial ID IRCT20240307061203N1. All procedures were conducted in accordance with the ethical standards outlined in the Declaration of Helsinki. Data collection involved a series of baseline assessments followed by post-intervention evaluations after a six-week intervention period. Trunk control was measured using the Trunk Control Measurement Scale (TCMS), while primitive reflexes were assessed through a screening questionnaire that categorized reflexes as present, absent, or overcome. Cognition was evaluated using the Hammersmith Infant Neurological Examination (HINE) Performa, Section III.

The intervention for Group A involved traditional neurodevelopmental techniques focusing on trunk control exercises, progressing through stages of muscle stimulation, weight shift, dynamic co-activation, and trunk rotation with elongation. Group B received a virtual reality-based intervention that combined neurodevelopmental trunk control exercises with immersive VR therapy, incorporating interactive games designed to enhance trunk control and motor function. Both groups participated in their respective interventions three times a week for six weeks, with sessions delivered by experienced pediatric physiotherapists who provided verbal and visual cues to facilitate motor skill development.

Statistical analysis was performed using SPSS version 27. Data normality was assessed using the Shapiro-Wilk test. Depending on the distribution of data, parametric tests such as paired t-tests and independent t-tests were used for normally distributed variables, while non-parametric tests, including Wilcoxon Signed Ranks and Mann-Whitney tests, were applied for variables that did not follow a normal distribution. The analysis aimed to compare the effects of neurodevelopmental treatment and virtual reality-based interventions on trunk control, gross motor function, cognition, and primitive reflexes within and between the intervention groups (1). Results were considered statistically significant if the p-value was less than 0.05. All statistical tests were performed by the same researcher to maintain consistency in data handling and analysis procedures.

This comprehensive approach ensured a thorough evaluation of the interventions' effectiveness, providing robust data on the impact of VR-based therapy compared to traditional neurodevelopmental methods in improving trunk control and related functional outcomes in children with developmental delays.

RESULTS

The study analyzed the effects of traditional neurodevelopmental treatment (NDT) and virtual reality-based neurodevelopmental treatment (VR-NDT) on trunk control, cognition, and primitive reflexes in children with developmental delays. Statistical analysis was conducted using SPSS version 27, with data normality assessed through the Shapiro-Wilk test.

Based on the normality results, appropriate parametric and non-parametric tests were applied to evaluate the outcomes within and between the groups. Below are the detailed results presented in a tabulated format, followed by a descriptive analysis.

Table 1: Between-Group Analysis of Trunk Control Measurement Scale (TCMS) and HINE Performa

Variable	Assessment	Group A (NDT-TCM) (mean ± S.D.)	Group B (VR-NDT-TCM) (mean ± S.D.)	t-Value/Z-Value	P-value
Trunk Control Measurement Scale	Pre-TCMS	13.81 ± 1.64	13.45 ± 3.49	0.308	0.761
	Post-TCMS	20.18 ± 2.40	24.18 ± 4.67	-2.59	0.017
HINE Performa (Conscious State)	Pre	9.95 ± 109.50	13.05 ± 143.5	-1.244	0.213
	Post	10.27 ± 80.0	15.73 ± 173.0	-3.350	<0.001
HINE Performa (Emotional State)	Pre	12.14 ± 133.5	10.86 ± 119.5	-0.540	0.589
	Post	8.27 ± 91.0	14.73 ± 162.0	-2.515	0.012
HINE Performa (Social Orientation)	Pre	12.50 ± 137.5	10.50 ± 115.5	-0.866	0.386
	Post	8.86 ± 97.50	14.14 ± 155.5	-2.153	0.031

Analysis: The analysis revealed that prior to the intervention, there were no significant differences in trunk control or cognitive parameters (conscious state, emotional state, and social orientation) between the NDT and VR-NDT groups. However, after the intervention, the VR-NDT group demonstrated significantly higher TCMS scores ($p = 0.017$), indicating superior improvement in trunk control compared to the NDT group. Additionally, significant improvements were observed in the VR-NDT group for cognitive parameters, including conscious state ($p < 0.001$), emotional state ($p = 0.012$), and social orientation ($p = 0.031$), suggesting a more pronounced impact of VR interventions on these outcomes compared to NDT.

Table 2: Within-Group Analysis of Primitive Reflexes

Primitive Reflexes	Assessment	Group A (NDT-TCM) (mean ranks ± sum of ranks)	Group B (VR-NDT-TCM) (mean ranks ± sum of ranks)	Z-Value	P-value
Moro Reflex	Pre	11.50 ± 126.50	11.50 ± 126.50	0.000	1.000
	Post	9.30 ± 93.00	12.55 ± 138.00	-1.62	0.105
STNR (Symmetric Tonic Neck Reflex)	Pre	11.00 ± 121.0	12.00 ± 132.00	-1.00	0.317
	Post	11.50 ± 115.0	10.55 ± 116.00	-0.953	0.340
Palmar Grasp Reflex	Pre	11.50 ± 126.5	11.50 ± 126.50	0.000	1.000
	Post	11.00 ± 110.50	11.00 ± 121.00	0.000	1.000
ASTNR (Asymmetric Tonic Neck Reflex)	Pre	12.50 ± 137.50	10.50 ± 115.50	-0.866	0.386
	Post	11.00 ± 110.50	11.00 ± 121.50	0.000	1.000
TLR (Tonic Labyrinthine Reflex)	Pre	11.50 ± 126.50	11.50 ± 126.50	0.000	1.000
	Post	11.00 ± 110.50	11.00 ± 121.50	0.000	1.000

Analysis: The analysis of primitive reflexes indicated no significant changes between the NDT and VR-NDT groups before and after the intervention. Both interventions did not result in statistically significant alterations in the responses of Moro, STNR, Palmar Grasp, ASTNR, and TLR reflexes, indicating that neither the NDT nor the VR-NDT interventions had a notable impact on primitive reflex integration in this study population

Summary of Results: The VR-NDT intervention demonstrated a significantly greater improvement in trunk control and cognitive outcomes (conscious state, emotional state, and social orientation) compared to traditional NDT, highlighting its potential as an effective rehabilitation strategy for children with developmental delays. However, both interventions showed similar effects on primitive reflexes, with no significant changes observed. These findings suggest that while VR-based neurodevelopmental treatment can enhance motor and cognitive functions, its impact on reflex integration may require further investigation or longer intervention durations to yield significant results.

DISCUSSION

The findings of this study provide valuable insights into the effectiveness of virtual reality-based neurodevelopmental treatment (VR-NDT) compared to traditional neurodevelopmental techniques (NDT) in improving trunk control and cognitive functions in children with developmental delays. The significant improvement observed in the VR-NDT group, particularly in trunk control, conscious state, emotional state, and social orientation, underscores the potential of VR-based interventions as an innovative and effective approach to pediatric rehabilitation (13). These results align with previous research that has demonstrated the positive impact of VR on motor functions and cognitive outcomes in children with various developmental disorders, including cerebral palsy and developmental coordination disorder (1). The interactive and engaging nature of VR, which leverages principles of neuroplasticity, likely contributed to the enhanced outcomes observed in this study, as it promotes active participation and provides real-time feedback, essential for motor learning and functional recovery (2).

In contrast, the study found no significant differences between the NDT and VR-NDT groups concerning primitive reflex integration, indicating that neither intervention had a notable impact on these reflexes. This finding is consistent with earlier studies suggesting that while VR can effectively enhance motor skills and cognitive functions, its influence on primitive reflexes, which are deeply rooted in the early stages of neurological development, may be limited or require longer intervention periods to observe significant changes (3). The persistence of primitive reflexes, such as the Moro and Palmar grasp reflexes, in children with developmental delays is often associated with underlying neurological conditions that may not be fully addressed by motor-based interventions alone (4). Therefore, the lack of significant change in primitive reflexes in this study suggests that additional or alternative therapeutic approaches may be necessary to target these aspects of neurodevelopment (15, 16).

The strengths of this study include its randomized controlled trial design, which minimizes bias and enhances the reliability of the findings. Additionally, the use of validated outcome measures, such as the Trunk Control Measurement Scale (TCMS) and HINE Performa, ensured that the improvements observed in trunk control and cognitive functions were accurately assessed (12). The study's innovative approach, integrating VR into neurodevelopmental treatment, also represents a significant advancement in pediatric rehabilitation, offering a personalized and engaging therapy option for children with developmental delays (17).

However, several limitations must be acknowledged. The relatively small sample size (n=22) may have limited the generalizability of the findings, as it may not fully represent the diverse population of children with developmental delays. Additionally, the short intervention period of six weeks may not have been sufficient to observe long-term effects, particularly concerning primitive reflex integration, which may require prolonged exposure to therapeutic interventions. Future studies should consider larger sample sizes and extended follow-up periods to better understand the long-term benefits and potential limitations of VR-based interventions in this population (5).

Furthermore, the study's exclusion criteria, which omitted children with severe mental abnormalities, visual impairments, and significant intellectual disabilities, may have limited the applicability of the findings to a broader range of children with developmental delays. Including these populations in future research could provide a more comprehensive understanding of the effectiveness of VR-NDT across different subgroups of children with varying levels of developmental impairments (6, 9).

In conclusion, this study demonstrated that VR-NDT is an effective intervention for improving trunk control and cognitive functions in children with developmental delays, offering a promising alternative to traditional NDT methods. However, the limited impact on primitive reflexes suggests that additional therapeutic approaches may be necessary to address these specific aspects of neurodevelopment. Further research with larger sample sizes, longer intervention periods, and more inclusive criteria is recommended to fully explore the potential of VR-based interventions in pediatric rehabilitation and to optimize therapeutic strategies for children with developmental delays (6).

REFERENCES

1. Ali F, Suleman R, Noor A, Ahmad I, Shakeel M, Aqeel M. Effectiveness of a Virtual Reality-Based Rehabilitation Program Versus Conventional Physical Therapy in Improving Motor Function and Balance in Stroke Survivors: A Randomized Controlled Trial. J Health Rehabil Res. 2023;3(2):817-821.
2. Biddiss E, Chan-Viquez D, Cheung ST, King G. Engaging Children with Cerebral Palsy in Interactive Computer Play-Based Motor Therapies: Theoretical Perspectives. Disabil Rehabil. 2021;43(1):133-147.
3. Hadders-Algra M. Early Diagnostics and Early Intervention in Neurodevelopmental Disorders: Age-Dependent Challenges and Opportunities. J Clin Med. 2021;10(4):861.
4. Brown KA, Parikh S, Patel DR. Understanding Basic Concepts of Developmental Diagnosis in Children. Transl Pediatr. 2020;9(Suppl 1).
5. Choo YY, Agarwal P, How CH, Yeleswarapu SP. Developmental Delay: Identification and Management at Primary Care Level. Singapore Med J. 2019;60(3):119.
6. Ebrahimisani S, Sohrabi M, Taheri H, Agdasi MT, Amiri S. Effects of Virtual Reality Training Intervention on Predictive Motor Control of Children with DCD: A Randomized Controlled Trial. Res Dev Disabil. 2020;107(4):103768.
7. Gibson V. Early Childhood Development Practitioners' Awareness of the Age Acquisition of Key Motor Milestones and Physical Activity Requirements for Children Birth to Four Years. J Dev Phys Disabil. 2021;31(7):267-277.

8. Goyal C, Vardhan V, Naqvi W, Naqvi WM. Virtual Reality-Based Intervention for Enhancing Upper Extremity Function in Children with Hemiplegic Cerebral Palsy: A Literature Review. Cureus. 2022;14(1).
9. Hua J, Williams GJ, Jin H, Chen J, Xu M, Zhou Y, et al. Early Motor Milestones in Infancy and Later Motor Impairments: A Population-Based Data Linkage Study. Front Psychiatry. 2022;13:809181.
10. Kakebeeke TH, Knaier E, Chaouch A, Caflisch J, Rousson V, Largo RH, et al. Neuromotor Development in Children: New Norms From 3 to 18 Years. Dev Med Child Neurol. 2018;60(8):810-819.
11. Keshner EA, Lamontagne A. The Untapped Potential of Virtual Reality in Rehabilitation of Balance and Gait in Neurological Disorders. Front Virtual Real. 2021;2:641650.
12. Lee KH, Park JW, Lee HJ, Nam KY, Park TJ, Kim HJ, et al. Efficacy of Intensive Neurodevelopmental Treatment for Children with Developmental Delay, with or Without Cerebral Palsy. Ann Rehabil Med. 2017;41(1):90-97.
13. Liu W, Hu Y, Li J, Chang J. Effect of Virtual Reality on Balance Function in Children with Cerebral Palsy: A Systematic Review and Meta-Analysis. Front Public Health. 2022;10:865474.
14. Marlow M, Servili C, Tomlinson M. A Review of Screening Tools for the Identification of Autism Spectrum Disorders and Developmental Delay in Infants and Young Children: Recommendations for Use in Low- and Middle-Income Countries. Autism Res. 2019;12(2):176-199.
15. Park M, Kim J, Yu C, Lim H. The Effects of Neurodevelopmental Treatment-Based Trunk Control Exercise on Gross Motor Function and Trunk Control in Children with Developmental Disabilities. Ann Rehabil Med. 2023;11(10):1446.
16. Scharf RJ, Scharf GJ, Stroustrup A. Developmental Milestones. Pediatr Rev. 2016;37(1):25-38.
17. Yue QJ, Wang XZ, Tang MS, Li JN, Chen ZW, Zhang YQ, et al. Effect of Super Early Comprehensive Rehabilitation on Neurodevelopmental Prognosis of High-Risk Infants. J Hainan Med Univ. 2019;25(3):73-77.
18. Zubler JM, Wiggins LD, Macias MM, Whitaker TM, Shaw JS, Squires JK, et al. Evidence-Informed Milestones for Developmental Surveillance Tools. Pediatrics. 2022;149(3).