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Effects of Virtual Reality–Assisted Physiotherapy on Motor Function and Balance in a Child with Spastic Cerebral Palsy: A Case Study

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Abstract:

- ***Background:***

Cerebral palsy (CP) is a non-progressive neurodevelopmental disorder characterised by impairments in motor control, balance, and functional mobility. Conventional physiotherapy remains the cornerstone of rehabilitation; however, maintaining motivation and facilitating effective motor learning in children with CP can be challenging. Virtual reality (VR)–assisted rehabilitation has emerged as a technology-supported intervention that may enhance engagement, task repetition, and neuroplasticity. Despite growing interest, evidence describing its individual-level clinical application remains limited.

- ***Case Presentation:***

An 8-year-old child diagnosed with spastic diplegic cerebral palsy, classified as Level II on the Gross Motor Function Classification System (GMFCS), presented with difficulties in balance, gait, and functional mobility. The child demonstrated reduced postural control, impaired selective lower-limb movements, and limited participation during conventional therapy sessions.

- ***Clinical Findings and Diagnosis:***

Based on clinical assessment and functional evaluation, impairments in gross motor function, dynamic balance, and gait quality consistent with spastic diplegic CP were identified. No additional neurological or musculoskeletal complications were noted.

- ***Therapeutic Intervention:***

The child received a structured rehabilitation program combining VR-based task-oriented training with conventional physiotherapy. The intervention was administered for 45 minutes per session, five days per week, over a period of six weeks. The VR component emphasised goal-directed activities, dynamic balance tasks, and lower-limb motor control using interactive visual feedback to promote motor learning and engagement.

- ***Outcomes:***

Post-intervention results showed clinically meaningful improvements in gross motor function, balance, gait parameters, postural control, selective lower-limb movement, and functional mobility (GMFM-88, Paediatric Balance Scale), along with increased motivation, participation, and therapy adherence.

- ***Conclusion:***

This case report indicates that VR-assisted physiotherapy is a feasible and effective adjunct to conventional rehabilitation in children with spastic cerebral palsy, improving motor outcomes and engagement. Further controlled studies are needed to confirm long-term efficacy and optimise intervention parameters.

Keywords: *Balance Training, Cerebral Palsy; Motor Learning; Paediatric Neurorehabilitation; Virtual Reality.*

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I. INTRODUCTION

Cerebral palsy (CP) is the most common cause of childhood physical disability, with a global prevalence estimated at 2–3 per 1,000 live births. It is defined as a group of permanent disorders of movement and posture attributed to non-progressive disturbances in the developing fetal or infant brain, often accompanied by sensory, cognitive, and musculoskeletal impairments. Among the various subtypes, spastic cerebral palsy is the most prevalent, accounting for approximately 70–80% of cases, and is characterised by increased muscle tone, hyperreflexia, and impaired voluntary motor control. These neuromuscular deficits frequently result in abnormal gait patterns, impaired postural control, and reduced balance, which limit functional independence and participation in age-appropriate daily and social activities.

Physiotherapy remains the cornerstone of rehabilitation in children with spastic CP, with the primary objectives of improving motor function, enhancing postural control, and promoting functional independence. Conventional physiotherapy interventions include task-specific practice, stretching and strengthening exercises, balance and coordination training, gait training, and neurodevelopmental techniques. Despite demonstrated benefits, conventional therapy may be constrained by limited engagement, motivational challenges, and difficulties in providing sufficient repetitions of goal-directed movements, which are critical for motor learning and neuroplastic adaptation. These limitations are particularly pronounced in paediatric populations, where sustained attention and motivation are key determinants of therapy adherence and functional gains.

Recent advances in technology-based rehabilitation have introduced virtual reality (VR) as an adjunctive tool in neurorehabilitation. VR-assisted physiotherapy offers an interactive, immersive environment that enables children to perform goal-directed, task-specific movements while receiving real-time visual, auditory, and sometimes haptic feedback. This multisensory feedback enhances motor learning by facilitating error detection, promoting repetitive practice, and providing immediate reinforcement of successful movements. Additionally, the gamified and engaging nature of VR interventions has the potential to improve motivation, adherence, and enjoyment, which are critical factors in paediatric rehabilitation outcomes.

Evidence supporting the use of VR-assisted therapy in children with CP has grown over the past decade. Studies suggest that VR interventions may improve balance, postural stability, upper and lower limb coordination, and functional mobility, potentially through mechanisms of neuroplasticity and sensorimotor integration. VR has also been shown to complement conventional physiotherapy by enabling safe, intensive practice of functional tasks that may be difficult to replicate in traditional therapy settings. However, most studies to date have focused on small cohorts or group interventions, and there remains a paucity of detailed case reports describing individualised VR-assisted physiotherapy programs, intervention rationale, and patient-specific outcomes in children with spastic CP.

II. PATIENT INFORMATION

An 8-year-old child diagnosed with spastic diplegic cerebral palsy was referred for physiotherapy management. The child was classified as Level II on the Gross Motor Function Classification System (GMFCS), indicating independent ambulation with limitations in balance and coordination.

The child was born prematurely at 32 weeks of gestation and exhibited delayed motor milestones. There was no history of seizures, sensory impairments, or recent orthopaedic or neurosurgical interventions. The child had previously received conventional physiotherapy, with reported challenges related to attention and motivation during sessions.

➢ *Informed Consent*

Written informed consent was obtained from the child's parent or legal guardian for participation in therapy and publication of this case report. The child's identity has been protected in accordance with ethical guidelines.

III. CLINICAL FINDINGS AND DIAGNOSTIC ASSESSMENT

➢ *Neuromuscular and Postural Examination*

On physical examination, the child demonstrated classical features of spastic diplegic cerebral palsy. Increased muscle tone was observed bilaterally in the hip adductors, hamstrings, and gastrocnemius muscles, consistent with lower limb spasticity. Selective motor control at the knee and ankle joints was reduced, limiting the child's ability to perform isolated joint movements during functional activities. Trunk stability was compromised during dynamic tasks, with difficulty maintaining an upright posture during transitional movements such as sit-to-stand and reaching in standing. Postural deviations were evident, including anterior pelvic tilt and increased lumbar lordosis during gait.

➢ *Functional and Gait Assessment*

Functionally, the child presented with significant limitations in gross motor performance. Balance deficits were noted during both static and dynamic activities, such as single-leg standing and gait initiation, resulting in frequent loss of balance during play. Gait analysis revealed reduced step length, decreased stride symmetry, and impaired weight transfer, particularly during single-limb stance. These impairments restricted participation in age-appropriate activities, including running, climbing, and playground play, thereby limiting functional independence in mobility.

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➢ *Standardised Outcome Measures*

Baseline assessment was conducted at Week 0 before intervention. Outcome measures included the Gross Motor Function Measure–88 (GMFM-88) to evaluate motor abilities across lying, rolling, sitting, crawling, standing, and walking domains; the Paediatric Balance Scale (PBS) to assess static and dynamic balance during functional tasks; and observational gait analysis to document spatiotemporal parameters, postural control, and weight transfer during walking.

IV. DIAGNOSTIC CLASSIFICATION

The diagnosis of spastic diplegic cerebral palsy was confirmed based on clinical history, neurological examination, and functional assessment in accordance with established diagnostic criteria. No additional musculoskeletal deformities, such as hip subluxation, scoliosis, or fixed joint contractures, were identified, and no neurological impairments beyond lower limb spasticity were present. The child was classified as Gross Motor Function Classification System (GMFCS) Level II, indicating independent ambulation with limitations in balance and coordination.

➢ *Rationale for Intervention*

This diagnostic profile characterised a combination of spasticity, impaired selective motor control, reduced balance, and altered gait mechanics, making the child suitable for targeted VR-assisted physiotherapy. The need for an intervention emphasising active engagement, repetitive task practice, and real-time feedback was evident to facilitate motor learning, postural control, and functional mobility. Baseline findings provided objective reference points for evaluating post-intervention changes in motor function, balance, and gait.

➢ *Therapeutic Intervention*

The intervention spanned six weeks, with sessions conducted three times per week, each lasting approximately 45–60 minutes. The program integrated virtual reality (VR)–assisted physiotherapy with conventional physiotherapy techniques to target the child's specific impairments, including spasticity, impaired selective motor control, balance deficits, and gait abnormalities.

➢ *Session Structure (45–60 minutes)*

- Warm-up: 5–10 minutes
- VR-assisted physiotherapy: 20–25 minutes
- Conventional physiotherapy: 15–20 minutes
- Cool-down and stretching: 5 minutes

➢ *Virtual Reality–Assisted Physiotherapy (20–25 Minutes)*

VR-based training utilised an interactive, game-oriented system providing real-time visual and auditory feedback to enhance engagement and motor learning.

- *Weight-Shifting Activities*

✓ *Dose:*
3–4 sets of 2–3 minutes.

✓ *Rest:*
1 minute between sets.

✓ *Progression:*
Increased speed, reduced base of support.

✓ *Goal:*
Improve dynamic balance and postural control.

- *Step and Reach Tasks*

✓ *Dose:*
3 sets of 8–10 repetitions per limb.

✓ *Progression:*
Increased reach distance and task complexity.

✓ *Goal:*
Enhance lower limb coordination and selective motor control.

- *Sit-to-Stand and Squatting Tasks*

✓ *Dose:*
3 sets of 8–12 repetitions.

✓ *Progression:*
Reduced upper-limb support, increased squat depth.

✓ *Goal:*
Strengthen hip and knee extensors and improve functional mobility.

- *Gait Simulation and Obstacle Negotiation*

✓ *Dose:*
5–7 minutes of continuous practice.

✓ *Progression:*
Increased walking speed and obstacle variability.

✓ *Goal:*
Promote gait symmetry, stride length, and effective weight transfer.

➢ *Conventional Physiotherapy (15–20 minutes)*

- *Stretching Exercises*

✓ *Target Muscles:*
hip adductors, hamstrings, gastrocnemius.

✓ *Dose:*
3 repetitions per muscle group.

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- ✓ *Hold:*
  20–30 seconds.
- ✓ *Goal:*
  Reduce spasticity and improve joint range of motion.

- *Strengthening Exercises*

- ✓ *Target Muscles:*
  trunk stabilisers, hip abductors, ankle dorsiflexors.
- ✓ *Dose:*
  2–3 sets of 8–12 repetitions.
- ✓ *Progression:*
  Resistance bands and functional positions.
- ✓ *Goal:*
  Improve postural stability and functional movement efficiency.

- *Functional Task Training*

- ✓ *Activities:*
  Standing balance tasks, overground walking, play-based activities.
- ✓ *Dose:*
  5–7 minutes.
- ✓ *Goal:*
  Facilitate skill transfer to daily functional activities.

V. OUTCOME ASSESSMENT

Clinical outcomes were evaluated at baseline (Week 0) and post-intervention (end of Week 6) using the Gross Motor Function Measure–88 (GMFM-88), Paediatric Balance Scale, and observational gait analysis to quantify changes in motor function, balance, and gait parameters.

Table 1 Clinical Outcomes

Outcome Measure	Baseline (Week 0)	Post-Intervention (Week 6)	Clinical Interpretation
GMFM-88 – Standing	52/100	64/100	Improved gross motor control and functional mobility in standing tasks
GMFM-88 – Walking	48/100	61/100	Enhanced gait ability, stride length, and weight-bearing capacity
Paediatric Balance Scale	35/56	45/56	Gains in static and dynamic balance; improved trunk stability and postural control
Observational Gait Analysis	Reduced step length, lower limb scissoring, asymmetrical weight transfer, trunk forward flexion	Increased step length, reduced scissoring, improved symmetry, better trunk alignment	Improved gait efficiency, coordination, and functional mobility
Engagement & Participation	Moderate; required prompting	High; actively participated, motivated, and attentive	Enhanced adherence and task engagement

VI. DISCUSSION

This CARE-compliant case report demonstrates that a six-week program of virtual reality (VR)–assisted physiotherapy, combined with conventional physiotherapy, resulted in meaningful improvements in motor function, balance, gait, and engagement in a child with spastic cerebral palsy. Post-intervention assessments revealed increased GMFM-88 scores, particularly in the standing and walking dimensions, reflecting enhanced gross motor control and functional mobility. Similarly, improvements in the Paediatric Balance Scale indicated gains in both static and dynamic balance, suggesting improved postural stability and trunk control during functional tasks. Observational gait analysis further corroborated these findings, demonstrating improved step length, better weight transfer, reduced lower limb scissoring, and improved trunk alignment during walking.

The observed improvements are likely attributable to the integration of motor learning principles within the VR-assisted intervention. Task-specific, repetitive practice in an enriched and interactive environment promotes motor skill acquisition and functional carryover. VR provides immediate visual and auditory feedback, enhancing error detection and correction, which may accelerate learning and facilitate neuroplastic changes. The engaging, game-like environment also appears to have contributed to heightened motivation, attention, and active participation, which are crucial for maximising therapeutic outcomes in pediatric populations, where adherence to conventional therapy can be challenging.

The combination of VR-assisted therapy with conventional physiotherapy allowed for complementary targeting of underlying impairments. Stretching and strengthening exercises addressed spasticity, selective motor control deficits, and trunk instability, while VR tasks provided functional, goal-directed practice that encouraged

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balance, coordination, and gait symmetry. This multimodal approach likely contributed to the improvements observed across multiple domains, supporting the principle of task integration in pediatric neurorehabilitation.

These findings align with emerging evidence suggesting that VR-based interventions can enhance rehabilitation outcomes in children with cerebral palsy. Previous studies have reported improvements in balance, gait parameters, and upper and lower limb function following VR-assisted therapy, likely mediated by increased sensory input, feedback-driven motor learning, and engagement. This case adds to the growing body of literature by demonstrating that lower-limb VR tasks specifically targeting balance and gait can produce clinically relevant gains in a child with spastic diplegia.

Despite these encouraging results, several limitations should be acknowledged. As a single-case report, the findings cannot be generalised to the broader population of children with cerebral palsy. The absence of long-term follow-up precludes conclusions regarding the retention of functional gains over time. Additionally, objective measures such as motion capture or instrumented gait analysis were not used, limiting precise quantification of biomechanical changes. The observed improvements may also have been influenced by natural developmental progression, caregiver involvement, or therapist encouragement.

VII. CLINICAL IMPLICATION

This case demonstrates that integrating VR-assisted physiotherapy with conventional exercises can effectively enhance motor function, balance, gait, and engagement in children with spastic cerebral palsy. The multimodal, task-specific approach supports motor learning, postural control, and functional mobility, while the interactive VR environment promotes motivation and adherence. Clinically, VR can serve as a valuable adjunct to traditional therapy, providing enriched, goal-directed practice that may accelerate skill acquisition and improve rehabilitation outcomes. Incorporating VR into pediatric neurorehabilitation programs could enhance therapy effectiveness and patient participation, particularly in children with motor control deficits and limited engagement in conventional exercises.

Future research should include larger sample sizes and controlled trials to establish the efficacy and optimal dosage of VR-assisted physiotherapy. Long-term follow-up studies are necessary to determine the durability of functional gains and the potential for transfer to daily activities. Investigating the integration of VR with other evidence-based interventions, including constraint-induced movement therapy or task-oriented training, may further enhance rehabilitation outcomes. Additionally, incorporating objective motion analysis and neurophysiological assessments could clarify the mechanisms underlying VR-induced neuroplasticity in pediatric populations.

This study is limited by its single-case design, which restricts the generalisability of findings to the wider cerebral palsy population. The absence of a control condition prevents attribution of improvements solely to the VR-assisted intervention. Lack of long-term follow-up limits conclusions regarding retention of gains. Outcome measures relied partly on observational analysis rather than instrumented gait assessment, reducing biomechanical precision. Additionally, developmental maturation, therapist interaction, and caregiver involvement may have influenced outcomes independent of the intervention.

VIII. CONCLUSION

This case report suggests that virtual reality–assisted physiotherapy, combined with conventional rehabilitation, is a feasible and effective approach for improving motor function, balance, gait, and engagement in a child with spastic cerebral palsy. Improvements in GMFM-88, Paediatric Balance Scale scores, and gait parameters indicate functional gains likely facilitated by task-specific practice, feedback, and enhanced motivation within the VR environment. While results are promising, limitations such as the single-case design and short-term follow-up highlight the need for larger controlled studies to confirm efficacy, determine optimal protocols, and evaluate long-term retention of functional improvements.

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