Case Series

Effects of a Robot-Assisted Equine-Movement Intervention on Postural Control and Standing Kinematics in Children With Cerebral Palsy: A Preliminary Observational Case Series

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Abstract

Introduction. Hippotherapy and horse-riding simulators have been proposed as complementary approaches to improve postural control and motor function in children with cerebral palsy, but evidence remains heterogeneous and advanced robotic equine-movement systems require further clinical investigation. To describe the short-term clinical and standing kinematic changes associated with a HIROB-based rehabilitation intervention in children with cerebral palsy characterized by impaired axial control and immature standing posture.

Methods. This preliminary observational case series included four children with cerebral palsy. Participants underwent a three-week HIROB-based intervention delivered 5 sessions per week, 45 minutes per session. Assessments were performed at baseline and after treatment using the Gross Motor Function Measure-88 (GMFM-88), the first-generation Paediatric Balance Scale (PBS), passive range of motion assessed with a goniometer, and instrumented standing analysis using the BTS Smart-DX-1000 system with the Davis protocol.

Results. All participants showed improvements in GMFM-88 total scores and PBS scores after treatment. Joint range of motion improved across the assessed parameters, with the most consistent changes observed in hip abduction and unilateral popliteal angle. Standing kinematic analysis showed a trend toward improved postural alignment, particularly in pelvic and hip parameters, with reduced asymmetry and

closer approximation to normative values.
Discussion. These preliminary findings suggest that HIROB-based rehabilitation may be feasible and may contribute to short-term improvements in standing alignment, joint mobility, and balance-related outcomes in selected children with cerebral palsy. Given the small sample size, absence of a control group, and concomitant rehabilitation context, the results should be interpreted as exploratory and hypothesis-generating.

Keywords: Cerebral Palsy, Hippotherapy, Robot-Assisted Rehabilitation, Equine Movement Simulation, Postural Control, Standing Kinematics, Pediatric Neurorehabilitation, Gross Motor Function, Balance, Range of Motion

Introduction

Cerebral palsy (CP) comprises a group of permanent disorders of movement and posture caused by a non-progressive lesion of the developing brain and is commonly associated with activity limitations that affect functional independence throughout childhood (Plotas et al., 2024, Obrero-Gaitán et al., 2022). In addition to the primary motor disorder, children with CP frequently present impaired postural control, balance deficits, abnormal muscle tone, reduced selective motor control, and gait abnormalities, all of which negatively influence daily activities, participation, and quality of life (Plotas et al., 2024, Obrero-Gaitán et al., 2022).

In recent decades, hippotherapy has gained increasing attention as a complementary rehabilitation approach in paediatric neurorehabilitation (Plotas et al., 2024, Corral Granados & Fernández Agís, 2011). Its neurophysiological rationale is based on the rhythmic, repetitive, and three-dimensional movement generated by the horse during walking, which provides continuous multisensory input and elicits ongoing postural adjustments by the rider (Corral Granados & Fernández Agís, 2011). This movement has been described as biomechanically comparable, at least in part, to pelvic and trunk displacement during human gait, thereby creating a task-specific environment in which trunk control, pelvic mobility, balance reactions, and postural alignment can be trained in a functional and motivating context (Corral Granados & Fernández Agís, 2011, Shurtleff et al., 2009, Kwon et al., 2011).

The available literature suggests that hippotherapy may positively influence several motor domains in children with CP. Previous studies have reported improvements in dynamic trunk and head stability, upper-limb reaching efficiency, gross motor performance, gait speed, stride length, pelvic kinematics, and functional balance following hippotherapy-based interventions (Shurtleff et al., 2009, Kwon et al., 2011). Additional evidence indicates favourable effects on muscle activation patterns and adductor symmetry, as well as on the reduction of hypertonicity in selected muscle groups, supporting the hypothesis that equine-assisted movement may contribute to more effective postural organization and motor control (McGibbon et al., 2009, Ribeiro et al., 2019). Recent reviews have generally supported the potential of hippotherapy to improve gross motor function, balance, coordination, gait-related outcomes, and postural performance, although they also highlight heterogeneity in treatment protocols, outcome measures, sample characteristics, and study design (Plotas et al., 2024, Martín-Valero et al., 2018).

Despite these promising findings, the use of real horse hippotherapy in clinical practice is often limited by logistical, environmental, and organizational constraints, including restricted accessibility, high costs, weather dependence, and difficulties in standardizing treatment intensity and movement characteristics (Obrero-Gaitán et al., 2022, Martín-Valero et al., 2018, Chinniah et al., 2020).

To address these limitations, horse-riding simulators and robotic equine-movement systems have been developed to reproduce, in a controlled and safer environment, the multidirectional and rhythmic characteristics of horseback motion

(Obrero-Gaitán et al., 2022, Chinniah et al., 2020, Ortega-Cruz et al., 2025). Systematic reviews and meta-analytic data suggest that simulator-based interventions may improve gross motor function, sitting ability, functional balance, and hip range of motion, particularly when combined with conventional physiotherapy (Obrero-Gaitán et al., 2022, Chinniah et al., 2020, Ortega-Cruz et al., 2025). More recent studies have also suggested positive effects on muscle tone, trunk postural control, gait-related parameters, and functional independence, reinforcing the potential value of simulator-assisted equine-movement training in paediatric rehabilitation (Obrero-Gaitán et al., 2022, Chinniah et al., 2020, Ortega-Cruz et al., 2025, Günay Yazıcı et al., 2025).

However, although hippotherapy and horse-riding simulators have shown promising effects on motor outcomes in children with CP, the available evidence remains heterogeneous, and clinically relevant questions are still open (Plotas et al., 2024, Obrero-Gaitán et al., 2022, Martín-Valero et al., 2018, Chinniah et al., 2020, Ortega-Cruz et al., 2025). In particular, treatment protocols are often not standardized, the duration and intensity of interventions vary considerably, samples are frequently small and clinically heterogeneous, and the relationship between changes in postural control and broader functional outcomes is not yet fully clarified (Plotas et al., 2024, Obrero-Gaitán et al., 2022, Martín-Valero et al., 2018, Chinniah et al., 2020, Ortega-Cruz et al., 2025). These limitations are especially relevant when considering advanced robotic systems, whose main advantage lies in the possibility of delivering a reproducible, adaptable, and measurable equine-like movement stimulus tailored to the child's clinical presentation.

Within this framework, HIROB is a robotic system designed to reproduce horse-like movement while allowing precise modulation of speed, intensity, and therapeutic task demands according to the patient's clinical characteristics. This feature makes it potentially suitable for targeting axial control, trunk-pelvis dissociation, postural alignment, balance reactions, and sensorimotor integration in children with CP within a highly standardized rehabilitation setting. From a clinical perspective, such a system may represent a useful complement to conventional therapy when the rehabilitation goal is to promote adaptive postural strategies, improve trunk organization, and facilitate motor control in a repetitive but customizable environment.

Therefore, the present preliminary observational case series aimed to describe the clinical effects of HIROB-based intervention in four children with cerebral palsy characterized by impaired trunk control and immaturity of standing posture. In particular, the study focused on changes in postural control, balance, gross motor function, joint mobility, and gait-related organization, to provide preliminary clinical data for the future development of structured rehabilitation protocols based on robot-assisted equine-movement systems.

Materials and Methods

Study design

This study reports preliminary observational data from a case series on the use of a HIROB-based rehabilitation program in four children with CP undergoing inpatient paediatric neurorehabilitation. Clinical and functional assessments were performed at baseline and repeated after the intervention period to explore pre-post changes associated with treatment.

Given the exploratory nature of the study and the limited sample size, no control group was included, and no between-group comparison was planned. The study was intended as a preliminary observational case series aimed at describing feasibility and potential short-term clinical changes associated with a structured HIROB-based intervention in children with CP characterized by impaired axial control and immaturity of standing posture. The study was conducted in accordance with the principles of the Declaration of Helsinki. The study included four children with cerebral palsy presenting a comparable clinical-functional profile characterized by impaired trunk control and immaturity of standing posture. All recruited participants presented a motor profile compatible with the use of the HIROB system and with the rehabilitative targets of the study, specifically postural control, trunk organization, balance, and motor function.

Eligibility criteria

Inclusion criteria

Children were eligible for inclusion if they met all the following criteria:

- diagnosis of CP with spastic diplegic or quadriplegic clinical presentation and Gross Motor Function Classification System (GMFCS) level III or IV.
- cognitive level within the normal range or consistent with mild intellectual disability.
- hip abduction range of at least 25 degrees.
- preserved receptive communication sufficient to understand simple verbal commands.
- age between 3 and 10 years.

Exclusion criteria

Children were excluded in the presence of any of the following:

- orthopaedic, bone, muscular, or neurosurgical procedures performed within 12 months before enrolment.
- botulinum toxin injections administered within 6 months before enrolment.
- visual field deficits or clinically relevant impairment of the vestibular-oculomotor system likely to interfere with treatment or assessment.
- moderate or severe intellectual disability.
- physical impairments considered incompatible with safe use of the HIROB system.

Outcome measures

All participants underwent a structured pre-post clinical assessment at the beginning and at the end of the intervention period. The same evaluator performed the assessments at both time points. The assessment protocol was designed to investigate the main domains potentially influenced by HIROB-based rehabilitation, namely visual-vestibular function, musculoskeletal mobility, postural control, balance, gross motor function, and gait-related performance. A functional vestibular-oculomotor assessment was performed to identify possible impairments capable of influencing postural organization, head control, balance responses, and motor performance during treatment.

Musculoskeletal assessment included the evaluation of passive joint range of motion (ROM) using a goniometer according to a standardized positioning protocol, with particular attention to the lower limbs and hip mobility. ROM assessment was used to verify clinical compatibility with device positioning and to document possible pre-post changes after treatment.

Postural control and balance were assessed using the first-generation Paediatric Balance Scale (PBS), to investigate functional balance performance in paediatric patients. Gross motor performance was assessed using the Gross Motor Function Measure-88 (GMFM-88). The total GMFM-88 score was calculated from the sum of the five domains and used to document possible changes in global motor function after the intervention.

Instrumented gait and static postural assessment were performed using the BTS Smart-DX-1000 system (BTS Bioengineering, Italy). The Davis protocol was used for marker placement and data acquisition. For each participant, three standing trials were acquired at baseline (T0) and after treatment (T1). Static standing analysis and gait analysis, where feasible according to the child's functional abilities, were used to explore changes in postural alignment and locomotor organization after treatment.

Intervention

All participants underwent a three-week individualized HIROB-based rehabilitation program integrated into the routine inpatient neurorehabilitation schedule. HIROB is a robotic system designed to support intensive, task-oriented, and highly reproducible rehabilitation interventions. Through controlled and assisted movement patterns, it facilitates active patient participation while ensuring safe and progressive motor training. HIROB promotes motor relearning by integrating repetitive practice, sensory feedback, and individualized exercise modulation. By combining treatment standardization with patient-specific adaptability, HIROB represents a valuable tool to enhance clinical rehabilitation pathways. The HIROB intervention was delivered 5 sessions per week, 45 minutes per session, for a total duration of 3 weeks. The intervention was specifically designed for children with reduced axial control and immature standing organization, with the aim of promoting postural adaptation, trunk-pelvis coordination, balance responses, and functional motor organization.

The therapeutic program was structured around three main macro-objectives:

1. exercises for functional head control.
2. exercises for functional trunk control.
3. exercises for functional standing organization.

Within these macro-areas, the activities were individualized according to each child's clinical profile, postural abilities, and adaptive responses. For each activity, the following elements were defined: specific goal, materials used, therapeutic request, execution modality, and clinical indicators of progression.

The HIROB system was used to provide rhythmic, multidirectional, and adjustable perturbations reproducing horse-like movement. Speed and intensity were modulated according to the child's trunk control, motor competence, and tolerance to the task. During treatment, the therapist adjusted the level of facilitation, the complexity of the task, and the sensory-motor demands according to the child's performance.

A representative example of the therapeutic logic was a head-control exercise based on visual tracking. In this task, the child, positioned in sitting, was asked to fix and maintain attention on a moving visual target while postural perturbations were generated by the HIROB device. The target was gradually moved in frontal, transverse, and oblique trajectories, and task duration, speed, and directional complexity were adapted according to the child's responses and level of competence.

Data analysis

Given the very small sample size and the exploratory observational design, data were analysed descriptively. Individual pre-post changes were examined for each participant, and outcome variation was interpreted in relation to each child's baseline clinical profile. No inferential statistical testing was performed. The aim of the analysis was not to establish treatment efficacy at a confirmatory level, but to provide preliminary clinical observations on the use of HIROB in children with CP presenting reduced trunk control and immature standing posture.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki. The reported data were obtained from routine clinical rehabilitation pathways performed during intensive inpatient rehabilitation. No additional intervention beyond standard clinical care was performed for research purposes. All data are presented in anonymized form, with no identifiable personal information.

Results

Participant characteristics

Four children with CP were included in this preliminary observational case series. The median age was 6.5 years, with an age range from 5 to 9 years. Three participants were female and one was male. Three children had spastic diplegia and one child had quadriplegia. According to the Gross Motor Function Classification System (GMFCS), three participants were classified as level III and one as level IV. Cognitive functioning was within the normal range in two children, borderline in one child, and characterized by mild delay in one child. At the oculo-vestibular assessment, two participants showed no relevant abnormalities, while two presented exophoria, bilateral in one case and right-sided in one case (Table 1).

Table 1. Baseline demographic and clinical characteristics of the participants. All participants presented impaired axial control and immaturity of standing posture, with a clinical profile compatible with HIROB-based rehabilitation.

Patient	Age, years	Sex	Diagnosis	GMFCS	Cognitive level	Oculo-vestibular findings
P1	7	M	Spastic diplegia	III	Borderline	Normal
P2	6	F	Spastic diplegia	III	Normal	Bilateral exophoria
P3	9	F	quadriplegia	IV	Mild cognitive delay	Normal
P4	5	F	Spastic diplegia	III	Normal	Right-sided exophoria

Functional outcomes

Gross motor function and balance outcomes are reported in Table 2 and depicted in Figure 1. All participants demonstrated improvements in GMFM-88 total scores following the intervention, with individual changes ranging from +2 to +6 points. PBS scores also increased in all subjects, with changes ranging from +3 to +6 points. Compared to GMFM-88, PBS improvements appeared more consistent across participants, showing a more homogeneous pattern of change.

Changes in joint range of motion are reported in Table 3. Overall, all participants showed improvements across the assessed joint parameters following the intervention.

The most consistent and marked increases were observed in hip abduction, with bilateral improvements ranging from +10 to +14 degrees across participants. Similarly, unilateral popliteal angle showed the greatest gains, with increases exceeding +12 degrees in all subjects

Table 2. Individual GMFM-88 total and PBS scores at baseline (T0) and after treatment (T1), with pre–post changes expressed as Δ.

Patient	GMFM T0	GMFM T1	Δ GMFM	PBS T0	PBS T1	Δ PBS
P1	72	74	2	20	26	6
P2	68	74	6	18	22	4
P3	60	64	4	15	19	4
P4	70	73	3	19	22	3

Table 3. Joint angles are expressed in degrees as pre–post values (T0→T1), with corresponding changes (Δ) in parentheses.

Patient	Hip Abd R	Hip Abd L	Hip Add R	Hip Add L	Popliteal Angle Unilateral R	Popliteal Angle Unilateral L	Popliteal Angle Bilateral R	Popliteal Angle Bilateral L	Plantarflexion R	Plantarflexion L
P1	34→46 (+12)	36→48 (+12)	26→30 (+4)	28→34 (+6)	136→150 (+14)	138→150 (+12)	142→150 (+8)	142→152 (+10)	142→144 (+2)	140→144 (+4)
P2	32→44 (+12)	34→48 (+14)	24→30 (+6)	26→30 (+4)	134→150 (+16)	136→150 (+14)	140→148 (+8)	140→150 (+10)	136→142 (+6)	138→146 (+8)
P3	30→40 (+10)	32→44 (+12)	22→28 (+6)	24→28 (+4)	132→146 (+14)	134→146 (+12)	138→146 (+8)	138→148 (+10)	136→140 (+4)	136→142 (+6)
P4	34→48 (+14)	36→48 (+12)	26→32 (+6)	28→32 (+4)	136→150 (+14)	138→152 (+14)	142→150 (+8)	142→152 (+10)	140→146 (+6)	140→146 (+6)

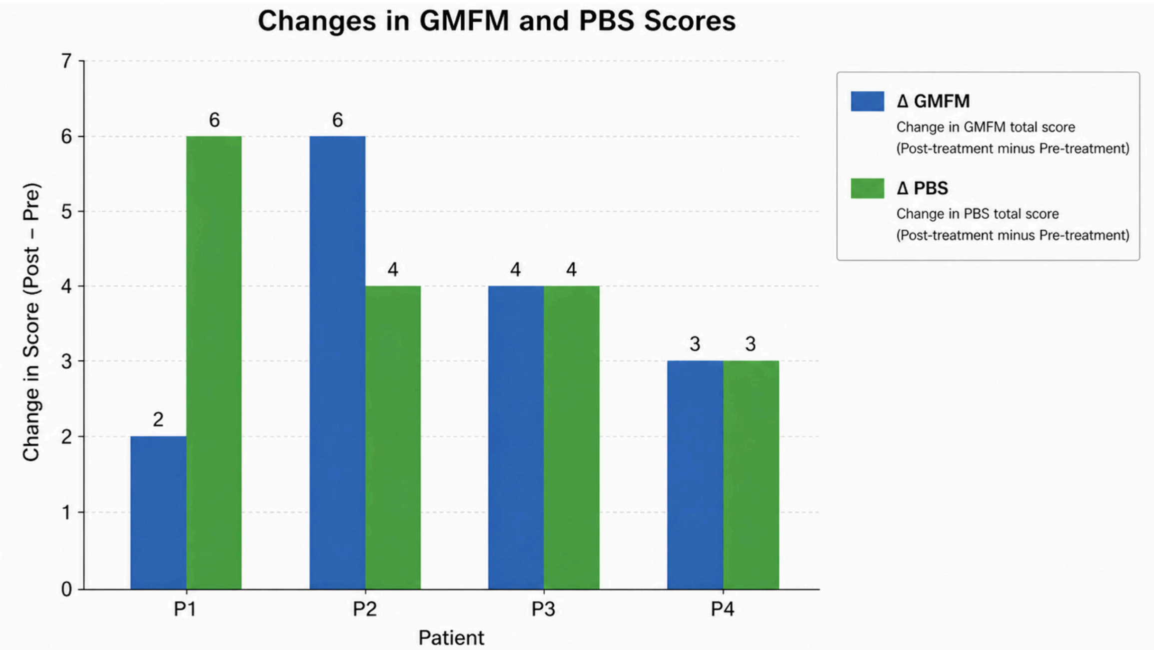

Figure 1. Individual changes in GMFM and PBS scores following the HIROB intervention. Bars represent pre–post differences (Δ) for each participant.

Legend. GMFM: Gross Motor Function Measure; PBS: Pediatric Balance Scale; Δ: change (Post – Pre).

and reaching up to +16 degrees in some cases.

Improvements in hip adduction were present but of smaller magnitude, generally ranging between +4 and +6 degrees. Changes in bilateral popliteal angle were more moderate, with increases between +8 and +10 degrees. Ankle plantarflexion showed variable and generally smaller changes across participants, with increases ranging from +2 to +8 degrees, without a consistent pattern.

Standing kinematic analysis

Standing kinematic parameters are illustrated in Figure 2. Overall, all participants showed a consistent trend toward normalization of joint alignment following the intervention, with reductions in pathological deviations and improved symmetry between sides. At baseline, all participants presented increased pelvic tilt and marked asymmetries in pelvic rotation. After the intervention, pelvic tilt values decreased bilaterally in all subjects, approaching the normative range. Similarly, pelvic rotation showed a substantial reduction in asymmetry, with right and left values becoming more balanced and closer to zero.

Hip kinematics showed positive pre-post changes across both planes. In the frontal plane, hip abduction/adduction values shifted toward normative values, with reduced excessive abduction and improved side symmetry.

In the sagittal plane, hip flexion angles decreased in all participants, indicating a reduction of the flexed posture observed at baseline. Knee kinematics showed a more variable pattern. In the sagittal plane, knee flexion decreased across participants, particularly on the left side, indicating a tendency toward a more extended and extended posture. In the transverse plane, knee rotation values moved toward normative ranges, with a reduction in excessive external rotation on the right side and greater bilateral symmetry.

Standing Kinematic Parameters Before and After HIROB Intervention

JOINT / PLANE	PRE (T0)								POST (T1)								NORMATIVE VALUES
	P1		P2		P3		P4		P1		P2		P3		P4		
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	Mean ± SD
PELVIS (Sagittal) Pelvic tilt (°) + = anterior tilt	17.3	17.3	16.2	18.0	18.5	16.8	15.8	17.6	7.9	7.9	8.8	8.3	9.4	8.7	7.6	8.1	10±4
PELVIS (Transverse) Pelvic rotation (°) + = right rotation	-14.3	14.3	-12.6	13.8	-15.1	12.9	-13.7	15.0	4.4	-4.4	3.9	-3.7	5.1	-3.9	4.7	-4.9	0±5
HIP (Frontal) Hip abd/add (°) + = abduction	4.5	5.9	5.2	6.4	4.8	6.1	5.6	5.4	0.8	4.1	1.4	3.6	1.2	3.8	1.1	3.2	0±3
HIP (Sagittal) Hip flex/ext (°) + = flexion	35.9	29.0	33.4	30.6	37.2	31.5	34.8	28.4	21.9	13.3	20.8	15.2	23.4	16.0	22.1	14.1	10±4
KNEE (Sagittal) Knee flex/ext (°) + = flexion	26.1	18.6	24.8	19.9	27.4	20.1	25.5	17.9	24.6	10.7	22.5	12.4	25.2	12.0	23.1	11.4	5±5
KNEE (Transverse) Knee rotation (°) + = external rotation	19.8	3.9	17.5	5.1	20.6	4.6	18.7	4.2	6.6	9.1	7.2	8.3	8.0	8.8	7.0	8.5	-10±5

R = right side
L = left side

Standing - Quiet Standing
Values are expressed as mean joint angles (degrees).
T0 = pre-intervention; T1 = post-intervention; SD = standard deviation.

Normative values are reported as mean ± SD.
Mini-bars show the normative band; dashed line indicates the mean.
Positive values follow the biomechanical convention listed per row.

Figure 2. Mean joint angles (degrees) are reported for each participant (P1–P4) in quiet standing, for right (R, green) and left (L, red) sides, at baseline (T0) and after the intervention (T1). Normative values (general population) are shown as mean ± standard deviation (SD), with the shaded bar representing the normal range (±2 SD) and the dashed line indicating the mean. Positive values are defined according to the biomechanical conventions reported for each variable.

Discussion

This preliminary observational case series explored short-term clinical and standing kinematic changes after a three-week HIROB-based intervention in four children with CP characterized by impaired trunk control and immaturity of standing posture. The main finding was a consistent descriptive trend toward more favourable postural organization in standing, with smaller deviations from normative kinematic values, particularly at the level of the pelvis and hip. These findings are consistent with the theoretical rationale of hippotherapy, according to which rhythmic, repetitive, and three-dimensional movement provides multisensory inputs capable of eliciting adaptive postural responses and facilitating neuromotor reorganization (Corral Granados & Fernández Agís, 2011, Shurtleff et al., 2009, Martín-Valero et al., 2018, Whalen & Case-Smith, 2012, Tseng et al., 2013). In this context, HIROB may reproduce some of the key therapeutic principles of horseback movement within a controlled and reproducible robotic environment.

The most relevant changes emerged from the standing kinematic analysis. After the intervention, pelvic tilt decreased bilaterally in all participants, approaching normative values, while pelvic rotation showed reduced asymmetry. This is clinically relevant because pelvic alignment plays a central role in both static postural organization and gait mechanics in children with CP (Kwon et al., 2011, Günay Yazıcı et al., 2025, Sterba et al., 2002). At the hip level, changes were observed in both frontal and sagittal planes. Hip abduction/adduction values shifted toward normative ranges, and excessive hip flexion decreased across participants. These results suggest an improvement in proximal alignment and trunk-pelvis organization. Similar changes have been reported after hippotherapy and horse-riding simulator interventions, which appear to promote trunk-pelvis coordination and more physiological lower-limb alignment through repetitive sensorimotor stimulation (Obrero-Gaitán et al., 2022, Chinniah et al., 2020, Ortega-Cruz et al., 2025, Park et al., 2014, Kwon et al., 2015). Knee kinematics showed a more variable pattern. Nevertheless, a general trend toward reduced flexion and more favourable rotational alignment was observed. These distal changes may reflect, at least in part, a secondary effect of improved proximal stability. The relationship between trunk-pelvis control and lower-limb biomechanics is particularly relevant in children with cerebral palsy, in whom compensatory postural strategies often influence hip, knee, and ankle alignment (Benda et al., 2003, Casady et al., 2004, Zadnikar & Kastrin, 2011).

A relevant aspect of the present findings concerns joint mobility. The most consistent descriptive increases were observed in bilateral hip abduction and unilateral popliteal angle. These changes may suggest a favourable effect on muscle extensibility and tone regulation, particularly in muscle groups commonly involved in spastic patterns, such as hip adductors, iliopsoas, hamstrings, and triceps surae.

Although muscle activity and tone were not directly measured in this study, previous works have shown that hippotherapy may promote more symmetrical muscle activation and reduce spasticity, especially in the lower limbs (McGibbon et al., 2009, Ribeiro et al., 2019, Hamill et al., 2007, Lucena-Antón et al., 2018, Hemachithra et al., 2020). Benda et al. reported improved muscle symmetry after equine-assisted therapy, while McGibbon et al. described changes in adductor activity and functional ability in children with spastic cerebral palsy (McGibbon et al., 2009, Benda et al., 2003). In line with these findings, the present ROM results may be interpreted as indirect clinical indicators of more favourable muscle balance and reduced hypertonic constraints, although this interpretation remains speculative.

The increase in unilateral popliteal angle is especially relevant because hamstring shortening and increased posterior-chain tone can influence pelvic position, knee flexion, and standing alignment. Similarly, increased hip abduction may reflect a reduction in adductor restriction, potentially supporting more favourable pelvic positioning and lower-limb alignment during standing.

Functional outcomes, assessed by GMFM-88 and PBS, showed positive pre-post changes in all participants. However, the magnitude of change was limited. This should be interpreted cautiously, considering both the small sample size and the ordinal nature of these clinical scales. GMFM-88 and PBS are useful tools for describing gross motor function and balance, but they may be less sensitive to subtle short-term biomechanical and postural changes in small case series.

Despite the modest numerical changes, the consistent direction of change across participants suggests a positive qualitative trend. This is also supported by the kinematic findings, which captured changes in postural alignment that may not be fully reflected by global functional scales.

Similar discrepancies between clinical scores and instrumented biomechanical measures have been described in previous rehabilitation studies, where gait or postural analysis detected changes not clear on ordinal clinical scales (Sterba et al., 2002, Herrero et al., 2012, Temcharoensuk et al., 2015, Champagne et al., 2017).

Clinical implications

The present findings suggest that HIROB may represent a promising adjunctive tool for children with CP characterized by impaired axial control and immature standing organization. By providing rhythmic, multidirectional, and adjustable perturbations, HIROB may support postural adaptation, trunk-pelvis coordination, balance reactions, and lower-limb alignment within a controlled rehabilitation setting. Its potential advantages over traditional hippotherapy include greater standardization, reproducibility, and easier integration into hospital-based pediatric neurorehabilitation programs (Obrero-Gaitán et al., 2022, Dominguez-Romero et al., 2020, Chang et al., 2021). These preliminary results are consistent with previous studies reporting positive effects of hippotherapy and horse-riding simulators on motor function, postural control, balance, gait-related outcomes, and quality of life in children with CP (Plotas et al., 2024, Obrero-Gaitán et al., 2022, Ortega-Cruz et al., 2025, Herrero et al., 2010, De Guindos-Sanchez et al., 2020, Dominguez-Romero et al., 2020, Deutz et al., 2018, Mutoh et al., 2019).

Limitations and future perspectives

This study has several limitations. First, the sample size was small, as expected in a preliminary case series. Second, the absence of a control group, randomization, and blinded assessment prevents causal inference regarding the effectiveness of the intervention. Third, the specific contribution of HIROB cannot be separated from the effects of concomitant rehabilitation, clinical variability, or short-term learning effects. Fourth, muscle tone and muscle activation were not directly assessed through objective measures such as electromyography or dynamometry. Finally, the short intervention period and lack of follow-up do not allow conclusions on the persistence of the observed changes over time.

Future studies should include larger samples and a control group receiving an alternative intervention with similar therapeutic objectives and comparable treatment intensity. Further research should also incorporate objective neuromuscular measures, such as surface electromyography, to better investigate the effects of HIROB on muscle activation, symmetry, and hypertonicity. Long-term follow-up would also be useful to determine whether postural and kinematic changes are maintained and whether they translate into meaningful improvements in gait, daily activities, and participation.

Conclusion

This preliminary case series suggests that HIROB-based rehabilitation is feasible and may be associated with short-term positive changes in standing alignment, joint mobility, and balance-related outcomes in selected children with CP. The observed changes support the potential role of HIROB in promoting postural reorganization, although the underlying neuromuscular mechanisms were not directly assessed. Given the small sample size, lack of control group, absence of blinded assessment, and concomitant rehabilitation context, these findings should be interpreted as preliminary and hypothesis-generating. Larger controlled studies with follow-up assessments are needed to clarify the efficacy of HIROB-based rehabilitation in pediatric CP.

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