ORIGINAL ARTICLE

Impacts of hippotherapy simulation on balance, postural control, and spasticity of thigh adductor muscles in children with spastic bilateral Cerebral Palsy: A single-blind clinical trial study

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ABSTRACT

Objectives

Cerebral Palsy (CP) is a group of movement disorders. A recently proposed occupational therapy approach to reduce spasticity and improve balance and postural control is Hippotherapy Simulation (HS). The present study attempts to investigate how HS impacts balance, postural control, and spasticity of adductor muscles in children with spastic bilateral CP.

Materials & Methods

Thirty-one children with bilateral spastic CP, five to nine years old, were selected via availability sampling and divided into the intervention group (n=16) and the control (n=15) through stratified block randomization. Assessment tools, including Pediatric Balance Scale (PBS), Trunk Control Measurement Scale (TCMS), Modified Ashworth Scale (MAS), Gross Motor Function Measure (GMFM), Pediatric Evaluation of Disability Inventory (PEDI), and goniometry, were completed by an assessor unaware of the children's grouping.

Results

After the intervention, the average total scores of all variables in the HS group significantly exceeded those in the control group (P<0.01). However, no significant differences were observed between the groups at follow-up, underlining the necessity of providing long-term or recurrent interventions to maintain improvements in gross motor function. This approach also constructively influenced postural control and mitigated the spasticity of adductor thigh muscles.

Conclusion

This study showed the multimodal effect of simulated hippotherapy combined with occupational therapy routine exercises on the physical performance of children with bilateral spastic CP.

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Introduction

Cerebral palsy (CP) is a non-progressive disorder that affects the immature human brain and adversely influences individuals' movement, posture, and muscle tone (1). Spastic CP has been regarded as the most common type of CP since 40% to 60% of children with CP fall into this category. In children with spastic CP, spasticity averts the development of motor function and acts as one of the significant causes of muscle disorders, leading to impairments in motor function, walking, balance, and body posture control (2). Spastic diplegia CP, as a prevalent form of CP, brings about a wide range of complications for children's mobility and motor function. The most influential issue amplifying this limitation is the spasticity of thigh muscles in these children (3).

In numerous studies, horse therapy has turned out to be an effective and efficient method in improving the balance problems (4) and postural control (5) of children with CP and reducing their spasticity (6). Hippotherapy and horse-riding therapy have been found to reduce the balance problems of children with CP (4). Hippotherapy promotes these children's balance, body posture, and coordination by improving hip, trunk, and thigh movements (5). Hippotherapy has short-term effects on the symmetry of the trunk and pelvic muscles (7, 8). To remove the restrictions of hippotherapy, including the inaccessibility and high costs of using horses in the process of rehabilitation treatments, the hippotherapy simulation (HS) technique, in which horses' movements are simulated and imitated, has been developed and has become widespread. By using SH machines, it is possible to experience horse riding indoors and in rehabilitation centers. The studies conducted on the short-term use of HS machines have demonstrated that by encouraging the imitation of horses' rhythmic movements, this method fosters muscle strength (9), a sense of balance and proprioception (10), and sitting motor function in children with spastic CP (11,12) and brings about a reduction in spasticity in the muscles of children with CP (2). Long-term sitting on HS devices can raise balance and postural control and decrease muscle spasticity in adductor thigh muscles in children with CP by stimulating proprioceptive receptors in the trunk and pelvis, improving abnormal tilt of the pelvis, and generating enduring tension in iliopsoas muscles and thigh adductors (13).

The studies that have been done so far have had different protocols. For example, in one study, the immediate effect of HRS on spasticity has been investigated (2). Furthermore, in other studies, the small sample size, the broad range of Gross Motor Function Classification System (GMFCS), the wide age range of 4-18 years, and the short intervention time of once a week were some of the problems of the previous studies (14). Ultimately, studies were required to have a follow-up phase to confirm the effectiveness and sustainability of HS interventions over time to ensure the comparability of the results across studies (12).

Therefore, the present study, as single-blind trial research, aimed to examine the impact of HS on balance, postural control, and spasticity of adductor muscles in children with spastic bilateral CP.

Material & Methods

Trial design

In the current study, as a single-blind randomized clinical trial, 5- to 9-year-old children with bilateral spastic CP were selected through availability sampling and assigned to two groups. After selecting the subjects based on the inclusion criteria, to randomly block children with stratified sampling, children with GMFCS II were placed in one group and children with GMFCS III in another group. Children were then randomly picked from each group using envelopes and randomly assigned to either control or intervention groups. This method considered an equal number of cards for each group.

Participants and settings

Thirty-six children with bilateral spastic CP were selected from an occupational therapy clinic located in Tehran.

The inclusion criteria were as follows:

1. Diagnosis of spastic cerebral palsy (including diplegia, double hemiplegia, and quadriplegia) by a neurologist.
2. Classified as either GMFCS level II or III.
3. Absence of behavioral problems.
4. A cognitive level above 70 in the Study of Participation of Children with Cerebral Palsy Living in Europe (SPARKLE).
5. No history of adductor surgery or Botox injections in the past six months.
6. No pelvic dislocation or partial dislocation as diagnosed by a doctor.
7. No history of seizures, particularly uncontrolled seizures or epilepsy.
8. No issues with the vestibular system.
9. No participation in hippotherapy or hippotherapy simulation services in the past year.
10. A spasticity score of 1 or +1 on the MAS.

Exclusion criteria were the unwillingness of the family or the child to continue the interventions and the occurrence of problems or illnesses for the child during the intervention. Figure 1 shows the flowchart diagram of the subjects' selection.

The flowchart diagram of the subjects' selection is shown in Figure 1.

Forty-three children with CP were screened, and 36 patients were randomly screened. The first child was recruited on 22 June 2023, and the last on 28 June 2023. Of these, follow-up data were available for 31 children to be included in the intention-to-treat analysis (Figure 1).

Table 1 presents the demographic and clinical characteristics of these children with CP. The mean age of the subjects was 6.90 (SD=1.70) years, and 51.6% were female. In this study, 12.9 % of mothers and fathers had a university education. Demographics and clinical characteristics were well-balanced between the HS and control groups (Table 1).

Notably, during the intervention, to prevent issues like sharing treatment details between the intervention and control groups, the clinic scheduled their visiting hours so the groups would not encounter each other.

Intervention

In the intervention group, in addition to providing children with CP with routine occupational therapy interventions and common treatments, including traditional neurodevelopmental approaches, Rood, sensory integration, splinting, and strength-enhancing exercises, the therapist used a simulated horse-riding machine. Out of 45 minutes of occupational therapy, half an hour was spent on routine occupational therapy interventions, and the last 15 minutes on simulated hippotherapy.

In the control group, the therapist spent the entire 45-minute session solely on standard occupational therapy interventions, just like in the intervention group.

Both groups participated in 15 sessions, each lasting 45 minutes, with three sessions held per week. Occupational therapists, familiar with the

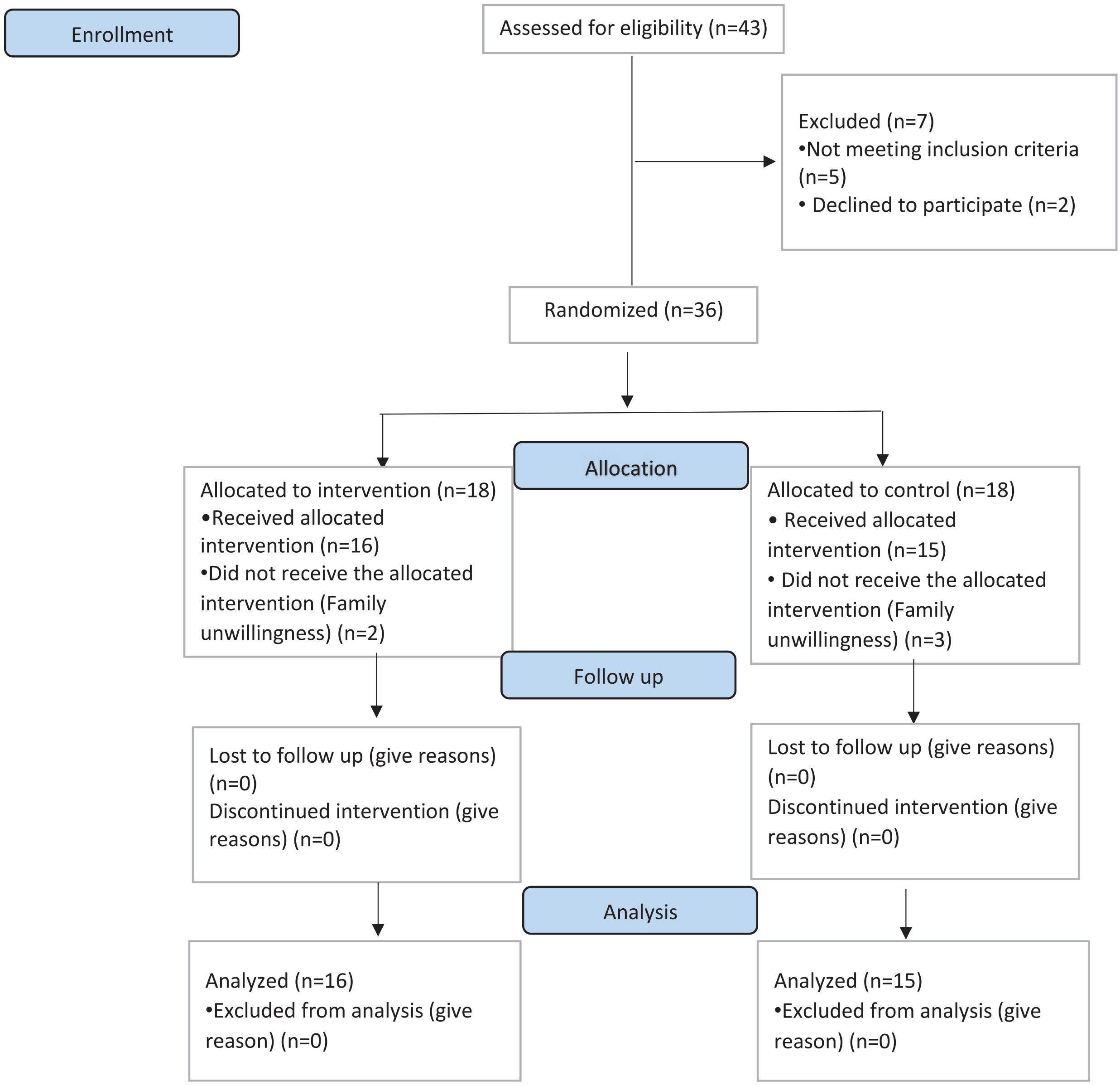

Figure 1. Participants' selection flowchart

children from their work at the clinic, conducted the routine exercises. Meanwhile, the researchers provided the HS program. One evaluator (with a bachelor's degree) was assigned to both groups. The evaluator, who was completely blinded to the subjects, performed all the evaluation phases, including initial evaluation, post-treatment evaluation, and follow-up.

Instruments

In the first session, all assessment tools, namely, PBS, TCMS, MAS**,** GMFM), PEDI, and goniometric measurement form to assess range of motion , were filled in by an evaluator who was unaware of the children's assigned group. After completing the interventions, the same evaluator, who was still uninformed about the children's assigned group, completed the PBS, TCMS, MAS, GMFM, and PEDI scales for both intervention and control groups and used goniometry to measure their joint range of motion. In order to assess the long-lasting effects of the intervention, at follow-up after two months, each child was re-evaluated with the above mentioned tools. During this

Table 1. Baseline characteristics of participants

	Total (n=31)	Group	
		Control (n=15)	HS (n=16)
Age (years), mean (SD*)	6.90 (1.70)	6.73 (1.79)	7.06 (1.65)
Gender, n (%)			
Male	15 (48.4)	8 (53.3)	7 (43.8)
Female	16 (51.6)	7 (46.7)	9 (56.2)
GMFCS level			
II	17(54/8)	8(53/3)	9(56/2)
III	14(45/2)	7(46/7)	7(43/8)

*SD: Standard Deviation; HS: Hippotherapy Simulation

period, both groups received routine occupational therapy interventions.

The device used in this study was OSIM uGallop OS-8600. This device has two keys: The first has predetermined movements, and the second has graded movements. This study used the first key for all clients.

Pediatric Balance Scale (PBS)

As a modified version of the Berg Balance Scale (BBS), the PBS scale was constructed by Franjoine et al. in 2003 to measure the balance of school-aged children (5 to 15 years old) with mild to moderate motion disorders. This scale was translated into Persian, and its validity and reliability were investigated for children with spastic CP in Iran by Alimi et al. 2019(16).

Trunk Control Measurement Scale (TCMS)

The TCMS is a clinical tool devised by Heyrman et al. (2011) to evaluate the postural control of trunk movement in children with CP. The child should be put in a sitting position without leaning on the back and without using hands as a support to score the items. The ICC for the overall score of this scale equals 0.97, and the inter-rater reliability is 0.98. Cronbach's alpha coefficient, used to gauge the internal consistency of the total score of the TCMS, is reported to be 0.94 (17).

Modified Ashworth Scale (MAS)

The MAS measures resistance during passive stretching of soft tissue. In this scale, the child is first put in the supine position with a soft pillow under his/her head. The child's thigh is then stretched from the closest position to the mid-line toward the furthest range, and it can move away from the mid-line (the point where the first soft resistance occurs). The MAS is scored during the child's movement from adduction to abduction (18).

Gross Motor Function Measure (GMFM)

The GMFM-88 comprises five domains: A) lying and rolling, B) sitting, C) crawling and kneeling, D) standing, and E) walking, running, and jumping.

In this study, sections D and E were evaluated. This scale was translated into Persian by Salehi et al. (2015), and the inter-rater and intra-rater reliabilities were excellent for all dimensions (ICC=0.99). Furthermore, Cronbach's alpha coefficients, computed to examine the internal consistency of the dimensions in GMFM-88, were acceptable ($0.78 < \alpha < 0.94$)(19).

Pediatric Evaluation of Disability Inventory (PEDI)

The PEDI was constructed by Haley et al. (1992) to measure the functional capabilities of children with disabilities. This scale assesses three subscales of functional skills, caregiver assistance, and modification. Each subscale evaluates performance in three domains: self-care, mobility, and social function. In the current study, 59 items related to mobility were examined. This instrument can be implemented in three ways: interviewing parents or caregivers, seeking the opinion of experts familiar with the child, or a combination of both. The first approach (i.e., interviewing parents or caregivers) was employed in the present study (20).

Goniometry

The reliability of the goniometry measurements in estimating the motion range of the lower limb joints in 1.5-to 9-year-old children with spastic CP was calculated by Mutlu et al. (2007). To measure the ROM of abduction, the child should lie on his/her back, and his/her hip and knee should be put in extension and flexion positions, respectively. The stationary arm of the goniometer should be aligned with the line joining the two anterior superior iliac spines, and its movable arm should be parallel to the longitudinal axis of the femur. Pelvic abduction is carried out smoothly and maintained until the range of motion ends. At this point, the degree displayed on the goniometer is recorded (21).

Results

PBS Total Score

In the pretest measurement, the PBS total score of the HS group was, on average, 3.63 (95% CI: 2.56 to 4.69) points higher than that of the control group ($F_{(1,28)}=48.83$, $P<0.001$, $\eta^2_P=0.636$) (Table 2). The effect size, calculated using partial eta squared, was 0.636, which is considered significant. This difference was insignificant in the follow-up measurement ($F_{(1,28)}=0.72$, $P=0.403$, $\eta^2_P=0.025$). The comparison of the mean PBS total score between the control and simulated hippotherapy groups in children with cerebral palsy is shown in Figure 2.

TCMS Total Score

In the pretest measurement, after adjusting for the pretest scores, the TCMS total scores of the HS group were significantly higher than those of the control group ($F_{(1,28)}=81.77$, $P<0.001$, $\eta^2_P=0.745$). Similar results were obtained for all the TCMS domains. In the follow-up measurement, the mean of TCMS total scores in the HS group significantly exceeded that in the control group ($F_{(1,28)}=4.71$, $P=0.039$, $\eta^2_P=0.144$), although the effect size in this measurement (0.144) was lower than the effect size in the pretest measurement (0.745). Children in the HS group scored, on average, 1.64 (95% CI: 0.55 to 2.73) points higher on the Selective Movement Control subscale than children in the control group in the follow-up measurement ($F_{(1,28)}=9.48$, $P=0.005$, $\eta^2_P=0.253$). The comparison of the mean TCMS total score between the control and simulated hippotherapy groups in children with cerebral palsy is shown

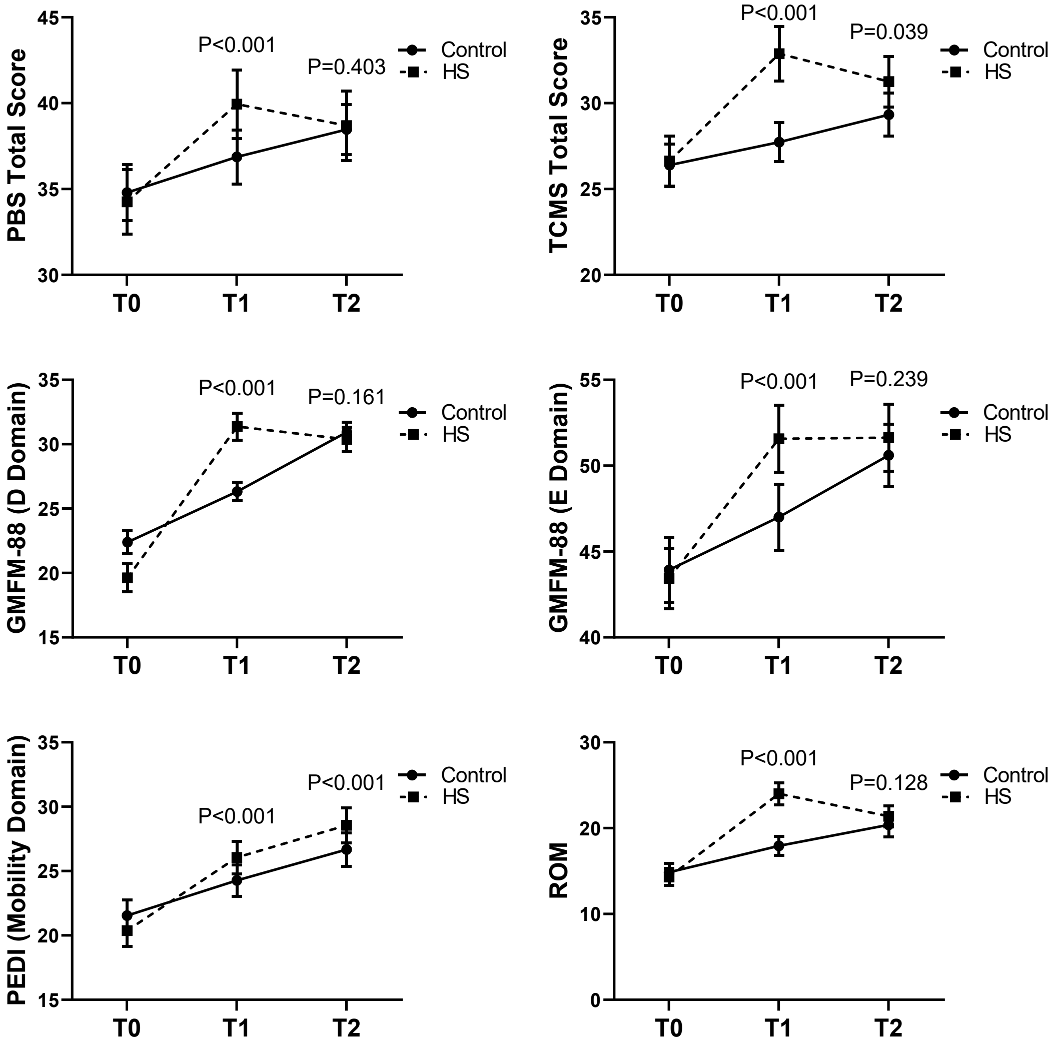

Figure 2. Between-group differences at pretest, posttest and follow-up assessments in children with CP

Graph row: evaluation times, Chart column: average variable scores

*T0: Pretest; T1: Posttest; T2: Follow-up; HS: Hippotherapy Simulation; PBS: Pediatric Balance Scale; TCMS: Trunk Control Measurement Scale; GMFM-88: Gross Motor Function Measure; D: Standing; E: Walking, Running, and Jumping; PEDI: Pediatric Evaluation of Disability Inventory; ROM: Range of Motion.

**Data are mean and 95% confidence interval (95% CI).

***P-Values are based on ANCOVA.

in Figure 2.

GMFM-88 (D: Standing and E: Walking, Running, and jumping domains)

In the pretest measurement, the HS group showed significant increases in Standing ($F_{(1, 28)}$ =324.32, P<0.001, η^2_P=0.921) and Walking, Running, and Jumping scores ($F_{(1, 28)}$ =45.77, P<0.001, η^2_P=0.620). However, these differences did not hold at the follow-up assessments (Table 2). The comparison of the mean score of subscale E (walking, running, and jumping) and the mean score of subscale D (standing) of GMFM-88 between control and simulated hippotherapy groups in children with cerebral palsy is shown in Figure 2.

Mobility

At the pretest measurement, the mobility scores in the HS group were significantly higher than those in the control group ($F_{(1,28)}$=26.84, P<0.001, η^2_P=0.489). A similar result, but with a lower effect size, was obtained at the follow-up measurement ($F_{(1,28)}$=12.39, P=0.001, η^2_P=0.307) (Table 2). The comparison of the average range of mobility score from the PEDI scale between the control and simulated hippotherapy groups in children with cerebral palsy is shown in Figure 2.

ROM

As presented in Table 2, after adjusting for the pretest scores, children in the HS group scored, on average, 6.66 (95% CI: 5.13 to 8.19) points higher on the ROM domain than children in the control group at the pretest measurement ($F_{(1,28)}$=79.48, P<0.001, η^2_P=0.739). At the follow-up measurement, the mean of ROM in the HS group was numerically higher than that in the control group, although this difference was not statistically significant ($F_{(1,28)}$=2.45, P=0.128, η^2_P=0.081). A medium effect size (0.081) was obtained. The comparison of the mean total ROM score between the control and simulated hippotherapy groups in children with cerebral palsy is shown in Figure 2.

Modified Ashworth Scale (MAS)

Table 2. ANCOVA results for between-group differences in different scales at pretest, posttest, and follow-up phases

	Group		Adjusted mean			
	Control	HS	difference (95% CI)[a]	$F_{(1,28)}$	*P*	η^2_P
PBS Total Score						
Pretest	34.80 (6.33)	34.25 (7.51)				
Posttest	36.87 (6.10)	39.94 (8.04)	3.63 (2.56 to 4.69)	48.83	<0.001	0.636
Follow-up	38.47 (5.64)	38.69 (8.15)	0.74 (-1.05 to 2.54)	0.72	0.403	0.025
TCMS Total Score						
Pretest	26.40 (4.76)	26.62 (5.85)				
Posttest	27.73 (4.42)	32.88 (6.31)	4.92 (3.81 to 6.03)	81.77	<0.001	0.745
Follow-up	29.33 (4.85)	31.25 (5.88)	1.71 (0.10 to 3.32)	4.71	0.039	0.144
TCMS- Static Sitting Balance						
Pretest	9.53 (1.19)	10.25 (1.95)				
Posttest	9.87 (1.13)	11.38 (2.06)	0.83 (0.32 to 1.34)	11.06	0.002	0.283
Follow-up	10.53 (1.13)	11.31 (2.02)	0.11 (-0.39 to 0.62)	0.20	0.655	0.007
TCMS- Selective Movement Control						
Pretest	12.00 (2.98)	11.44 (3.41)				

Continued Table 2.

Posttest	12.60 (2.97)	15.44 (3.60)	3.39 (2.60 to 4.17)	78.43	<0.001	0.737
Follow-up	13.27 (3.39)	14.38 (3.32)	1.64 (0.55 to 2.73)	9.48	0.005	0.253
TCMS- Dynamic Reaching						
Pretest	4.87 (0.83)	4.94 (0.93)				
Posttest	5.27 (0.80)	6.06 (1.12)	0.73 (0.27 to 1.19)	10.68	0.003	0.276
Follow-up	5.53 (0.92)	5.56 (1.15)	-0.03 (-0.62 to 0.56)	0.01	0.929	0.001
GMFM- D Domain						
Pretest	22.40 (3.42)	19.62 (4.38)				
Posttest	26.33 (2.82)	31.38 (4.22)	7.47 (6.62 to 8.32)	324.32	<0.001	0.921
Follow-up	30.93 (3.08)	30.38 (3.79)	1.28 (-0.54 to 3.10)	2.07	0.161	0.069
GMFM- E Domain						
Pretest	43.93 (7.27)	43.44 (7.09)				
Posttest	47.00 (7.44)	51.56 (7.84)	5.07 (3.54 to 6.61)	45.77	<0.001	0.620
Follow-up	50.60 (7.06)	51.62 (7.84)	1.48 (-1.04 to 4.01)	1.45	0.239	0.049
PEDI- Mobility						
Pretest	21.53 (4.73)	20.38 (4.90)				
Posttest	24.27 (4.73)	26.06 (5.07)	2.92 (1.76 to 4.07)	26.84	<0.001	0.489
Follow-up	26.67 (5.05)	28.56 (5.43)	3.03 (1.26 to 4.79)	12.39	0.001	0.307
ROM						
Pretest	14.87 (4.03)	14.31 (3.88)				
Posttest	17.93 (4.30)	24.00 (5.02)	6.66 (5.13 to 8.19)	79.48	<0.001	0.739
Follow-up	20.40 (5.34)	21.38 (4.81)	1.57 (-0.48 to 3.63)	2.45	0.128	0.081

*HS: Hippotherapy Simulation; PBS: Pediatric Balance Scale; TCMS: Trunk Control Measurement Scale; GMFM-88: Gross Motor Function Measure; D: Standing; E: Walking, Running, and Jumping; PEDI: Pediatric Evaluation of Disability Inventory; ROM: Range of Motion.

**Data are mean (SD) unless otherwise specified.

***Between-group differences were examined using ANCOVA (after adjusting for pretest scores).

****$\eta 2p$ values of 0.01-0.06, 0.06-0.14, and >0.14 were considered small, medium, and large effect sizes, respectivel

Based on the Cochran-Armitage test for trend, the severity of spasticity in the HS group was significantly lower than that in the control group at the post-test measurement (*P* for trend=0.002) (Figure 3). At the follow-up measurement, there was no statistically significant difference in MAS scores of the two groups (P for trend=0.766).

Discussion

The results indicated a significant increase in the total score of the PBS scale immediately after simulated hippotherapy, confirming the efficiency of this intervention in enhancing balance. This improvement corroborates that the HS intervention has rapid and substantial effects on the subjects' ability to maintain balance as a critical element in activities of daily living. The obtained large effect sizes demonstrate that the simulated hippotherapy accounts for a significant proportion of the total variance in the PBS scores, further highlighting the clinical significance of the observed progress in balance maintenance. The high effect sizes not only verify the great internal validity of the study but also accentuate the practical relevance of the intervention to the real-world clinical setting. A systematic review and meta-analysis study conducted by Obrero-Gaitan et al. (2022) revealed that compared to physiotherapy, therapy based on horse-riding simulation was more effective in improving gross motor function, functional balance, and the range of motion of pelvic abductors in children with CP(12), consistent with the findings of the present study regarding balance improvement. Similarly, a study performed by Choi et al. (2014) showed the considerable impact of simulated hippotherapy on static balance in children with CP (22). The elevated static balance in these children also provided empirical support for the efficiency of simulated hippotherapy in postural control.

Although the immediate impacts of the intervention on balance are considerable, at follow-up, despite the continuation of routine therapy interventions, the simulated hippotherapy and control groups achieved approximately similar PBS scores. These results can be ascribed to the fact that balance, as a multifaceted skill, is determined by various factors. The immediate

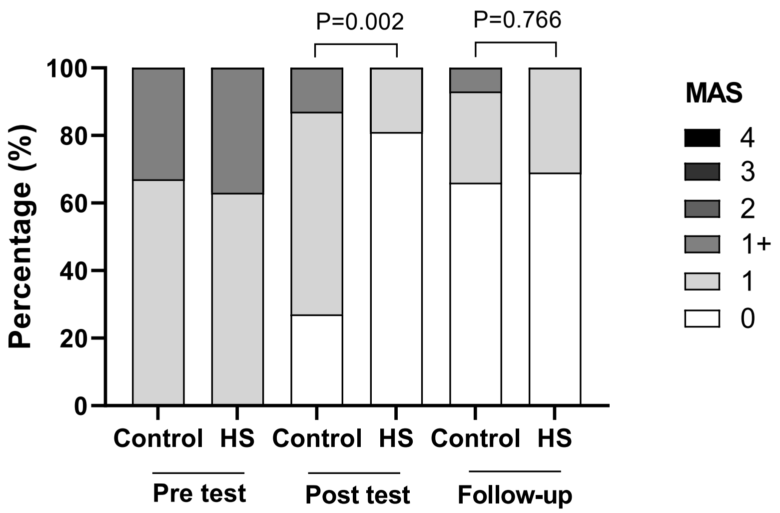

Figure 3. Distribution of MAS scores in control and HS groups
HS: Hippotherapy Simulation; MAS: Modified Ashworth Scale.
**P-Values is based on the Cochran-Armitage test for trend.

effect of simulated hippotherapy may address specific aspects of balance, but sustained improvement may require ongoing intervention or additional targeted strategies.

Compared to the intervention group, the control group underwent slower but more stable changes to the follow-up phase. The average scores of the intervention group, despite their regression from the second phase of the intervention to the follow-up phase, were higher than those of the control group at the end of the follow-up phase. However, this difference was not significant. These results indicated that after receiving two-month routine occupational therapy, the intervention group yielded results similar to those of the control group. Seemingly, occupational therapy can be highly effective; nonetheless, more time is required to achieve the same results.

While the immediate impact of simulated hippotherapy on balance is evident, the lack of significant differences in the follow-up phase underscores the necessity of precisely examining the sustainability of the intervention effects over time. Investigating individual differences in response to this intervention may contribute to identifying influential factors in long-term balance outcomes. Furthermore, undertaking qualitative assessments or seeking participants' and caregivers' feedback can provide more insights into the perceived challenges and benefits of balance improvement over time (23).

Developing gross motor function, particularly in standing, walking, running, and jumping, implies the constructive role of simulated hippotherapy in the principal functional domains. The results demonstrated a significant boost in the ability of the hippotherapy group to stand after the intervention compared to that of the control group. The rhythmic movements encouraged by hippotherapy activate the neural circuits associated with motor learning. Its repetitive patterns stimulate neuroplasticity (24), improving gross motor function. This development is of great clinical significance since it reflects improved weight-bearing and balance as two vital elements for daily life activities. The large effect size obtained for standing indicated that a large proportion of the variance in the scores of the standing domain was attributed to simulated hippotherapy, which signifies not only the statistical but also the clinical significance of the intervention effect and underlines the validity of the observed improvement.

At follow-up, the average standing score of the hippotherapy group was lower than that of the control group, but this difference was not statistically significant. Like other domains in this study, the average scores of the control group in this domain had slow but continuous progress. Although at the follow-up phase, the intervention group's average walking, running, and jumping scores exceeded those in the control group, the difference was statistically insignificant.

The reduced effect size values of standing and walking, running, and jumping at follow-up, as compared to the post-intervention phase, showed deterioration in these dimensions during follow-up. This suggests that while initial improvements are remarkable, the long-term development maintenance may require ongoing simulated hippotherapy or specific additional support. These findings highlight the necessity of tracking the sustainability of improvements in gross motor function after providing simulated hippotherapy.

Herrero et al. (2012) assessed sitting balance (domain B in the GMFM scale) in children with CP receiving simulation hippotherapy and found significant improvements. In their study, children with more severe disabilities exhibited more significant progress in sitting balance. However, consistent with the results of the present study, this development was not maintained during follow-up. In other words, no significant difference was detected between the control and intervention groups at the end of the follow-up phase (14). In a similar vein, the results of the systematic review and meta-analysis study conducted by Obrero-Gaitán et al. (2022) indicated that compared to physical therapy, HS intervention was a promising way of enhancing gross motor function, functional balance and the range of motion of hip abductors in children with CP. In their meta-analysis study, Obrero-Gaitán et al. (2022) recommended conducting further research, particularly on long-term effects, quality of life, and independence, suggesting future directions in this area(12). The first one (long-lasting effects of such interventions) was explored in the present study.

The follow-up phase not only offers opportunities to provide continuous intervention for maintaining the improvement of gross motor function but also paves the way to detect potential predictors of sustained development. Determining influential factors, such as adherence to home exercise programs, engagement in physical activities outside therapy sessions, and environmental changes, may help identify strategies to support and preserve long-term motor function outcomes. Furthermore, participants' experiences navigating daily activities after the intervention can be recorded through qualitative interviews, providing rich and valuable contextual understanding (25).

The findings of this study suggest the substantial short-term effects of the HS intervention as the hippotherapy group made a significant improvement in the TCMS total score compared to the control group. It was observed that all the domains of the TCMS were bolstered, confirming an all-inclusive constructive effect of HS on various dimensions of trunk control. Although, in the hippotherapy group, the effect size was smaller in the follow-up phase than in the immediate post-intervention phase, the trunk control of this group was significantly higher than that of the control group. This suggests that the benefits offered by the intervention are substantially maintained over time.

The considerable augmentation of 'selective movement control' in the hippotherapy group at follow-up highlights distinct beneficial impacts of hippotherapy on this dimension of trunk control. This development can facilitate completing functional activities requiring precise and coordinated movements. However, the results did not exhibit significant differences between the two groups in terms of 'static sitting balance' at follow-up, implying that while improvements in 'selective movement control' are long-lasting, the intervention may have a restricted effect on specific aspects of 'static sitting balance' in the long run. Moreover, the obtained insignificant differences in 'dynamic reaching' at follow-up suggest that, like 'static sitting balance,' this specific dimension may eventually remain unaffected over a long period. In line with the present study, Silva e Borges et al. (2011) demonstrated that simulated hippotherapy substantially contributed to the postural control of children with CP sitting position(26).

Overall, the dynamic and multidimensional horse movements challenge the rider's sense of balance and proprioception. As the child adjusts to horse movements, his/her trunk muscles are frequently stimulated to maintain stability. The repeated activation of trunk muscles strengthens the core muscles and raises trunk stability. Boosting trunk stability directly helps control body posture more efficiently. The child can retain an upright position more efficiently when the core muscles are strong and responsive. The results of this study verify the first hypothesis that assumed a significant reduction in spasticity, especially in the thigh adductor muscles. The achieved results are in accordance with the results of Hemachithra et al. (2020), who reported positive effects of horse-riding simulation on the spasticity of thigh adductor muscles in children with CP(2). Similarly, in a pilot study, Hemachithra et al. (2019) observed the effectiveness of simulated hippotherapy in lessening spasticity and increasing the motion range of the hip joint in children with spastic CP (27). Nevertheless, in the systematic review and meta-analysis study conducted by Obrero-Gaitán et al. (2022), no substantial differences were found between HS therapy and physical therapy in terms of spasticity alleviation in hip adductors, knee extensors, and ankle dorsiflexors(12). This suggests that although simulated hippotherapy can be beneficial in spasticity reduction, it may not necessarily be superior to other therapeutic interventions, such as physical therapy.

Hippotherapy, even in its simulated form, activates multiple physiological pathways. Rhythmic horse movements stimulate proprioceptive input, enhance neuromuscular coordination, and facilitate muscle relaxation. Furthermore, gentle rocking movements may cause inhibitory reflexes, decreasing muscle tone (28). Notably, spasticity results from a complex interaction of neurological, biomechanical, and environmental factors (29). Therefore, although the results of the present study reveal general positive effects, it is also essential to consider individual differences. Some children may respond more constructively to hippotherapy than others. As a result, it is required to devise and implement personalized treatment plans.

The follow-up phase offers opportunities to conduct long-term investigations on spasticity reduction and explore personalized treatment approaches tailored to different spasticity profiles. Qualitative measurements, such as pain assessment and quality of life evaluation, provide a more profound understanding of how spasticity mitigation affects children's overall well-being (30). Examining the role of caregiver training and support in managing spasticity-related challenges outside therapy sessions may give valuable information to optimize intervention outcomes.

The results of the present study demonstrated a significant improvement in the range of motion of children with CP as a function of simulated hippotherapy. These findings help therapists realize the therapeutic benefits of simulated hippotherapy, specifically in increasing the flexibility and mobility of hip joints. The results showed a substantial increase in the range of motion in the hippotherapy group compared to the control group after the intervention. The large effect size in the post-intervention phase indicated that a significant proportion of variations in hip joint range of motion was attributed to simulated hippotherapy, indicative of the considerable effects of this intervention. However, at follow-up, the effect size was reduced, and no significant difference was observed in the range of motion of the simulated hippotherapy and control groups. Although the immediate effect of the intervention on range of motion was significant, these improvements were not maintained over time. These results highlight the necessity of assessing the sustainability of the intervention effects and suggest that additional factors or long-term interventions may be required to maintain or further elevate gains in the range of motion.

Comparing these results with those of previous studies discloses their similarities in positive effects. Studies centering around the impact of horse-riding simulation exercises on children with CP have observed improvements in various dimensions, including posture, spinal alignment, and static balance, which indirectly help increase the range of motion. In their meta-analysis, Oberro-Gaetano et al. (2022) also introduce horse-riding simulation as an effective way of improving gross motor function, functional balance, and hip abductor range of motion in children with CP (12).

In line with the present study's results, Choi et al. (2014) found the effectiveness of simulated hippotherapy in improving trunk alignment and hip stability in children with CP, which indirectly helped increase the range of motion (22). In a similar vein, a pilot study revealed the efficiency of simulated hippotherapy in reducing spasticity and improving the hip joint range of motion in children with spastic CP (27). In their randomized clinical trial, Herrero et al. (2010) analyzed the therapeutic impacts of using a commercial hippotherapy simulator on several factors like motor development, balance control, hip abduction range of motion, and electromyographic activity of adductor muscles in CP children (14). They found that this intervention promoted the hip joint range of motion.

The insignificant difference in range of motion at follow-up should be interpreted cautiously. Future studies can explore the role of long-term or repeated interventions in maintaining and maximizing improvements in hip mobility over time. Individual differences in response to this intervention and the potential influence of other factors, such as child growth and development, can also be investigated.

As pointed out earlier, the results confirm an immediate increase in the hip joint range of motion. Nevertheless, the insignificant results at follow-up show a need to detect new ways of maintaining functional gains in mobility and flexibility. Identifying effective strategies to incorporate movement-based activities into daily routines (beyond the structured intervention period) may result in constant improvements in the range of motion (31). In addition, the longitudinal assessments of musculoskeletal health and joint integrity can help overcome potential barriers to sustained range of motion development (32).

The control group displayed slow improvements in all the domains, while the intervention group initially had a sharp increase in the domains but then experienced slower progress in the absence of simulated hippotherapy at follow-up.

Study limitations

This study has faced some limitations that need to be addressed. One of them was the withdrawal of several participants during the intervention, which reduced the sample size. Another issue was some families' low educational levels, making it difficult for them to complete the tools.

In Conclusion

This study showed the multimodal effect of simulated hippotherapy combined with occupational therapy routine exercises on the physical performance of children with bilateral spastic cerebral palsy. The immediate improvement in children's balance scale scores indicates the effectiveness of the intervention in increasing balance. However, the lack of significant differences during the follow-up phase suggests the need for sustainable intervention strategies to maintain long-term balance. Similarly, improving gross motor performance, especially in standing, walking, running, and jumping, showed a positive effect of simulated hippotherapy. While the immediate effects were significant, the lack of significant differences at follow-up emphasizes the importance of long-term or repeated interventions for sustained gains in gross motor function. In addition, this study highlighted a positive effect on postural control and reduced spasticity of the adductor thigh muscle. However, exploring the long-term effects of this intervention remained a critical issue for future research. An immediate post-intervention improvement in hip range of motion was evident, but the follow-up phase showed a reduction in effect size, emphasizing the need for sustained intervention strategies to maintain gains in hip mobility.

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Authors' Contribution

Kiana Ramezani, Minoo Kalantari and Marzieh Pashmdarfard: Study concept and design. Sara Rahmanian, Kiana Ramezani and Ghodrat Khavari: Aquisition of data. Alireza Akbarzadeh Baghban and Marzieh Pashmdarfard: Analysis and interpretation of data. Kiana Ramezani and Marzieh Pashmdarfard: Drafting of the manuscript. Minoo Kalantari: Editing the manuscript. All authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Conflict of Interest

No potential conflict of interest was reported by the authors.

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