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Effect of halliwick aquatic therapy and a land-based homologous program on postural control in children with cerebral palsy

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ABSTRACT

Background: This study explores whether the effectiveness of Halliwick aquatic therapy is attributable to the mechanical properties of water, to the therapeutic exercise program developed during the sessions, or to a combination of both. This study aimed to determine the effect of Halliwick Aquatic Therapy and a homologous land-based program on postural control in children with cerebral palsy aged 5 to 15 years classified as GMFCS levels I, II, and III.
Methods: A controlled clinical trial with a crossover design was conducted. Seventeen children participated, with a mean age of 9 years, most of them with hemiparesis. Each child received both interventions: Halliwick aquatic therapy and a land-based homologous program. The initial intervention was randomized. Postural control was assessed using the Pediatric Berg Scale and dimension E of the Gross Motor Function Measure. Analyses included intra- and inter-sample differences, as well as repeated measures ANOVA.
Results: Balance improved significantly with both interventions ($p<0.01$). Gross motor function improved with both interventions but only reached significance on land ($p<0.001$). Significant differences were found in the improvement of balance between the interventions. ($p=0.017$), with greater improvement on land. The sequential application of both interventions significantly improved both balance ($p<0.001$) and gross motor function ($p=0.013$).
Conclusions: The land-based program homologous to Halliwick Aquatic Therapy significantly improves gross motor function and balance in children with CP. A combined approach of consecutive therapies is recommended to optimize outcomes.

Keywords: aquatic therapy, cerebral palsy, exercise therapy, gait, neurological rehabilitation, postural balance.
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INTRODUCTION

Halliwick® Therapy is a concept that facilitates the learning process of postural, movement, and functional patterns. Its goals focus on acquiring skills that enable participation and social integration. It is considered one of the most important strategies in pediatric hydrotherapy, owing to its neurophysiological and motor control approach.[1-2]

Since its inception, Halliwick® Therapy has been grounded in the principles of motor learning, particularly through McMillan's proposal. Using a trial-and-error method, McMillan, together with his wife and team, developed an approach that enabled independent movement in water. This process of postural stabilization followed by independent mobility gave rise to the well-known Ten-Point Program.[2-3]

The ten points of the Halliwick® program are divided into three phases: mental adjustment/adaptation, balance control and independence in water, and movement.[4] These phases are carried out without flotation devices, fostering motor control and the execution of movements across the three body axes (sagittal, transverse, and longitudinal) with the aim of achieving a stable posture. This therapeutic model is also supported by the principle of core stabilization, applying active and dynamic strategies to facilitate movement and sensory integration.[5]

The sensory and proprioceptive stimulation provided by the aquatic environment is key in the treatment of patients with neurological disorders such as cerebral palsy (CP), as it allows movements to be performed with less effort, enhances the possibility of assistance or resistance, and promotes socialization.[6-7]

The main purpose of this study was to determine the effect of Halliwick Aquatic Therapy and a homologous land-based program on postural control in children with cerebral palsy aged 5 to 15 years. The theoretical foundation lies in Bouguer's theorem, which states that a body in water is subject to two opposing forces—gravity and buoyancy—achieving balance when both act along the same vertical line.[8] The reduced gravitational field of the aquatic medium decreases mechanical body load, which may facilitate postural control training.

On the other hand, posture is mainly linked to the body, whereas balance is related to space, forming an essential axis for achieving gross motor function milestones during psychomotor development.[9] Epidemiological studies estimate that between 60% and 80% of children with CP present moderate to severe impairments in balance and postural stability, which significantly affect motor performance, daily activities, and participation.[10-12]

In this context, the following question arises: Do the effects of the aquatic environment truly benefit postural control compared to the land environment, where a greater gravitational force acts? Hence, the need emerges to investigate and compare both interventions, applying the same principles of the ten points of Halliwick, and to assess whether the outcomes are greater, equal, or lesser.

The practical application of motor learning principles in CP rehabilitation involves the repetition of task-specific activities, postural adjustments, and anticipatory control strategies that strengthen the core musculature and promote the acquisition of stable movement patterns, both in water and on land.[13-14]. In the aquatic environment, these principles are reinforced through resistance and multidirectional sensory input; on land, the full action of gravity increases postural demand, promoting core stabilization and trunk control, essential for functional mobility.[15-16]

Balance and vertical postural control are essential components of gross motor skills, as they involve the ability to recover from and anticipate instability. Their absence directly affects performance in activities of daily living.[17] Closely related to these components, spatial orientation, as part of postural control, refers to the individual's ability to move the body while aligning trunk and postural tone, particularly under the action of gravity in a non-aquatic environment.[18]

However, despite the clinical relevance of both aquatic and land-based interventions, a clear research gap persists. To date, no studies have directly compared Halliwick Aquatic Therapy with a land-based program designed under identical neurophysiological and motor control principles. Previous works have focused exclusively on the aquatic method2,7,9,17, or on land-based interventions with different methodological foundations11,12,14,19,20, but not on homologous programs.[8] This study aims to fill that gap by systematically comparing both environments under equivalent therapeutic frameworks.

This therapeutic approach contributes to improving quality of life, fostering functional autonomy, promoting health and well-being, and facilitating better integration both in aquatic and terrestrial environments. Therefore, the present study explores whether the effectiveness of Halliwick therapy is attributable to the mechanical properties of water, to the therapeutic exercise program, or to a combination of both factors.

METHODS

Under an empirical-analytical approach with explanatory scope, a randomized controlled clinical trial with a crossover experimental design was conducted (**Figure 1**). A purposive (non-probabilistic) sampling was conducted with children with CP aged 5 to 15 years who met the inclusion and exclusion criteria from the cities of Pereira, Cali, and Neiva (Colombia). Given the crossover design, the sample size was calculated for a single group, which received both interventions: HAT and LBHTP. The sample size was calculated using the formula for comparing means, with a 95% confidence level, 80% statistical power, and standard deviations of 22.18 and 17.42 points for the Pediatric Berg Scale (0–56 points) and dimension E of the GMFM (0–100 points)21-22, respectively. Validation of the GMFM-66 in the Colombian population was also considered.23 The expected differences were calculated at 19 and 15 points, respectively.

Inclusion criteria were children of both sexes, affiliated with the Colombian social health security system, aged 5 to 15 years, diagnosed with CP at GMFCS levels I, II, or III (Gross Motor Function Classification System), and capable of using assistive devices.

Exclusion criteria included: children with intellectual disability, hearing impairment greater than 30 decibels (assessed through clinical testing), uncorrected visual impairment, open wounds, gastrostomies, unstable epileptic seizures, infectious or febrile processes, or contagious skin conditions.

Participants

Seventeen children aged 5 to 15 years (9 ± 3.4) completed both interventions. Most were male (59%), from low and middle socioeconomic strata (88%), affiliated with the contributory health system (71%), in preschool education (53%), with right-hand dominance (65%), and with normal weight status (88%) (**Tables 1 and 2**). The most prevalent cause, type, and period of occurrence of CP were cerebral ischemia (65%), spastic type (82%), and perinatal occurrence (82%). The most common distribution of motor impairment was hemiparesis (64%) (**Table 2**). **Figure 2** shows the flow diagram of recruitment, allocation, follow-up, and participation analysis.

Instruments

A questionnaire and anamnesis were applied to record general information and sociodemographic and clinical variables. Medical records were reviewed to verify inclusion and exclusion criteria. Postural control was assessed using the Pediatric

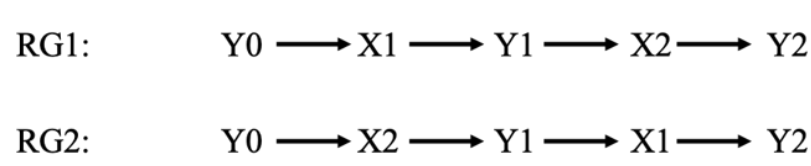

Figure 1. Study design flowchart of a crossover randomized controlled clinical trial.
R, randomization; G1, group 1: began with Halliwick aquatic therapy (HAT) and finished with the land-based homologous therapy program (LBHTP); G2, group 2: began with LBHTP and finished with HAT; Y0, pretest measures of postural control; Y1, posttest measures of postural control after the first intervention; Y2, posttest measures of postural control after the second intervention; X1, HAT; X2, LBHTP.

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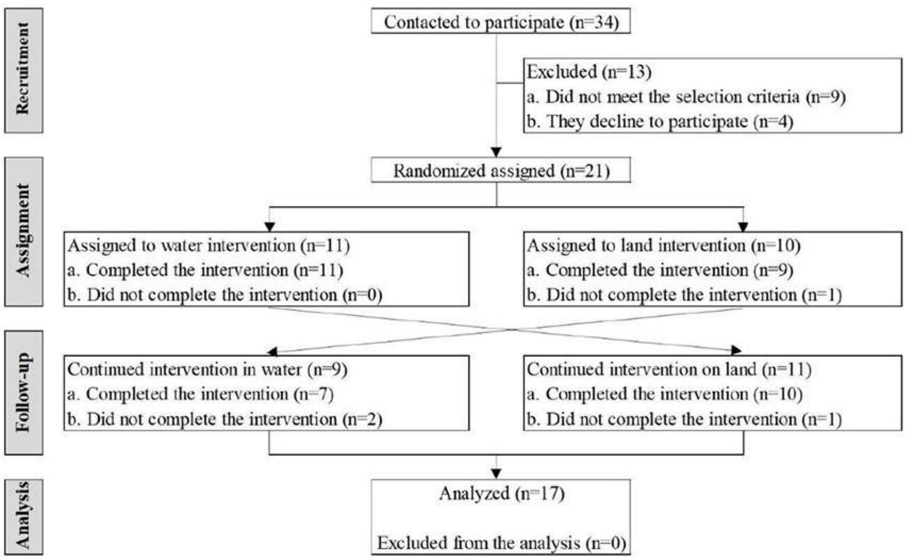

Figure 2. Participant flowchart

Table 1. Descriptive statistics of quantitative variables

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Age (years)	17	5	15	9.0	3.4
Weight (kg)	17	16	50	28.2	12.4
Height (cm)	17	104	160	127.6	19.9
Body mass index (kg/m2)	17	13.1	23.7	16.6	3.4
GMFM - Dimension E (0-100)					
Pretest	17	10	99	56.0	28.9
Posttest 1	17	10	100	58.7	30.9
Posttest 2	17	10	100	61.8	29.9
Pediatric Berg Scale (0-100)		¥			
Pretest	17	9	98	59.1	31.8
Posttest 1	17	9	100	64.6	32.5
Posttest 2	17	9	100	67.0	31.9

Cm, centimeter; GMFM - Dimension E, gross motor function measure - walking, running, and jumping; kg, killogram; m2, meter squared; N, number of participants.

Berg Scale (balance) and dimension E (walking, running, and jumping) of the Gross Motor Function Measure (GMFM-88).[21-22]

Procedure

The following procedure was carried out: a pilot test for the standardization, training, and calibration of neurotherapeutic procedures and postural control assessment; recruitment of study participants according to the calculated sample size; acceptance and signing of informed consent and assent; application of the pretest, including the Pediatric Berg Scale and GMFM-E, administered by physiotherapist researchers in accordance with test guidelines, with all tests video-recorded for each participant; implementation of the first physiotherapeutic intervention program (HAT or LBHTP) for 6 weeks, with three sessions per week according to group allocation, conducted by three graduate students in neurorehabilitation; application of the first posttest with video recording of all tests for each participant; implementation of the second

Table 2. Descriptive statistics of patient characteristics

Variable	N	Percentage (%)
Sex		
Male	10	59
Female	7	41
Socioeconomic condition		
Low	8	47
Medium	7	41
High	1	12
Affiliation to SHS		
Contributory	12	71
Subsidized	5	29
Education		
Preschool	9	53
Third	1	6
Fifth	1	6
Sixth	3	18
Eighth	1	6
Tenth	1	6
None	1	6
Handedness		
Right	11	65
Left	6	35
Weight status		
Normal	15	88
Overweight	1	6
Obesity	1	6
Period of occurrence of CP		
Prenatal	2	12
Perinatal	14	82
Postnatal (up to 2 years)	1	6
Type of CP		
Spastic	14	82
Dyskinetic	2	12
Mixed	1	6
Distribution of motor deficiency		
Left hemiparesis	6	35
Right hemiparesis	5	29
Triparesis	3	18
Paraparesis (lower limbs)	2	12
Quadriparesis	1	6
Cause of CP		
Cerebral ischemia	11	65
Trauma	3	18
Other	2	12
Prematurity	1	6

CP, cerebral palsy; N, number of participants; SHS, social health security

Table 3. Analysis of intrasample differences

Intervention	Variable	Pre-test	Post-test	Difference	P-value	Cohen *d*	*r*	Power
Land	GMFM-E (0-100)	56.99	61.39	4.40	<.001	1.02	0.990	0.98
	Pediatric Berg (0-100)	62.76	66.37	3.61	<.001	1.50	0.997	1.00
Water	GMFM-E (0-100)	57.65	59.07	1.42	0.057	-0.41	0.994	0.37
	Pediatric Berg (0-100)	61.00	65.30	4.30	0.002	0.91	0.989	0.93

GMFM - Dimension E, gross motor function measure - walking, running, and jumping.

intervention program; application of the second posttest with video recording of all tests for each participant; completion of evaluation forms based on videos from the three evaluation time points (pretest, posttest 1, and posttest 2); entry of data into the database; systematization, tabulation, graphing, and data analysis; and discussion of the results.

Bias control

Information bias was minimized by applying internationally validated tests in Spanish. Measurement bias was controlled through calibration and blinding of evaluators; one researcher, blinded to the interventions administered to the participants, completed the evaluation forms based on assessments performed by another researcher using video recordings of all tests at the three time points. The three researchers were located in different cities, measurements were taken at the same time for all participants, and evaluations strictly followed the application guidelines. Selection bias was addressed by carefully selecting participants according to the inclusion and exclusion criteria, with medical diagnoses obtained directly from clinical history documents. Intervention bias was reduced by applying standardized and protocolized intervention programs delivered by trained physiotherapists who were graduate students in neurorehabilitation.

Statistical analysis

Data processing was performed using SPSS version 29.0 (Statistical Package for the Social Sciences). For all analyses, two-tailed hypothesis tests were conducted with a 95% confidence level ($p \leq 0.05$) and 80% statistical power ($\beta - 1 \geq 0.80$). The results are presented in four subtopics: characterization of the overall outcomes of postural control variables and normality testing for the dependent variables at pretest, posttest, and for change measures (pretest vs. posttest); intrasample differences, analyzed using Student's t-test for related samples or Wilcoxon's Z test, depending on whether the assumption of

Table 4. Analysis of intersample change differences

Variable	Land (Post - Pre)	Water (Post - Pre)	Difference	P-value	Cohen *d*	Power
GMFM-E (0-100)	4.41	1.42	2.99	0.017	0.760	0.574
Pediatric Berg (0-100)	3.60	4.30	-0.70	0.781	-0.186	0.081

GMFM - Dimension E, gross motor function measure - walking, running, and jumping.

Table 5. Repeated measures analysis of variance (ANOVA)

Variable	Sphericity		Intra-subject effects				
	W Mauchly	P-value	DF	F	p	η2	Power
GMFM-E (0-100)	0.819	0.224	2.00	13.01	<.001	0.449	0.995
Berg Pediatric (0-100)	0.441	0.002	1.28	35.94	<.001	0.692	1.000

η2, eta squared; DF, degrees of freedom; F, for GMFM-E sphericity is assumed, for Pediatric Berg Scale the Greenhouse-Geisser test

Table 6. Post hoc analysis for repeated measures (Bonferroni test)

Variable	Measure		Difference of means	Deviation Error	P-value	95% CI for the difference	
						Lower	Upper
GMFM-E (0-100)	Pretest	Posttest 1	-2.7	1.109	0,078	-5.7	0.2
		Posttest 2	-5.8	1.347	0,002	-9.4	-2.2
	Posttest 1	Pretest	2.7	1.109	0,078	-0.2	5.7
		Posttest 2	-3.1	0.930	0,013	-5.6	-0.6
	Posttest 2	Pretest	5.8	1.347	0,002	2.2	9.4
		Posttest 1	3.1	0.930	0,013	0.6	5.6
Pediatric Berg (0-100)	Pretest	Posttest 1	-5.5	1.056	<,001	-8.3	-2.7
		Posttest 2	-7.9	1.172	<,001	-11.0	-4.8
	Posttest 1	Pretest	5.5	1.056	<,001	2.7	8.3
		Posttest 2	-2.4	0.496	<,001	-3.7	-1.1
	Posttest 2	Pretest	7.9	1.172	<,001	4.8	11.0
		Posttest 1	2.4	0.496	<,001	1.1	3.7

CI, confidence interval; GMFM - Dimension E, gross motor function measure - walking, running, and jumping.

normality was met, with determination of effect size (Cohen's d), correlation coefficient, and statistical power (β – 1); intersample differences, analyzed using Student's t-test for independent samples or the Mann–Whitney U test, depending on whether the assumption of normality was met, with determination of effect size (Cohen's d) and statistical power (β – 1); and comparison of repeated measures to assess postural control at pretest, posttest 1, and posttest 2. Repeated-measures ANOVA (within-subject) was performed, including tests of homogeneity of variances (Mauchly's test of sphericity), within-subject effects (sphericity assumed for GMFM and Greenhouse–Geisser correction applied for the Pediatric Berg Scale), explanatory model analysis (partial eta squared), reliability analysis (observed power), and multiple comparisons using the Bonferroni post hoc test. Mean differences are reported with their corresponding 95% confidence intervals and standard deviations.

RESULTS

Descriptive statistics and normality tests

In the pretest, the mean scores for GMFM dimension E and the Pediatric Berg Scale, on a 0–100 scale, were 56 and 59 points, respectively, ranging from 10 to 99 for the first test, and 9 to 98 for the second (table 1). Both the first and second post tests showed a progressive increase in the mean scores of both tests (**table 1**).

Shapiro–Wilk tests for the dependent variables generally indicated normal distributions for GMFM-E, both in the land-based and aquatic interventions ($p>0.050$). By contrast, the Pediatric Berg Scale tests generally indicated non-normal distributions ($p<0.050$). Based on these results, the subsequent inferential analyses were performed using parametric and non-parametric statistics, respectively.

Intrasample differences analysis

Statistically significant differences were found between pretest and posttest scores in both gross motor function (walking, running, and jumping) and balance when the land-based intervention homologous to Halliwick was applied, with a large effect size [$p<.001$; $d>1$; $R\geq0.99$; $\beta\text{-}1\geq0.98$]. Increases in scores were observed on both scales: GMFM-E and Berg Pediatric Scale (**Table 3**).

For the aquatic intervention using the Halliwick method, significant differences were found only between pretest and posttest balance scores, with a large effect size [$p=0.002$; $d=0.91$; $R=0.99$; $\beta\text{-}1=0.93$]. An increase in the score on the Pediatric Berg Scale was observed (**Table 3**).

Intersample differences analysis

Significant differences were found in the change measure (difference between pre- and posttest) of gross motor function (walking, running, and jumping) between the land-based and aquatic interventions, with a moderate effect size [$p=0.017$; $d=0.76$]. During the land-based intervention, children increased their GMFM-E scores more than during the aquatic intervention, with a difference of 3 points (**Table 4**). However, statistical power was not significant [$\beta\text{-}1=0.57$], which may be explained by the small sample size.

No significant differences were found in balance improvement between the land-based and aquatic interventions [$p=0.781$; $d=-0.70$; $\beta\text{-}1=0.081$].

Repeated measures ANOVA

Statistically significant differences were found among the measures of gross motor function related to walking, running, and jumping (GMFM-E, 0–100), with a moderate effect size [$F(2)=13.01$; $p<.001$; $\eta2=0.449$; $\beta\text{-}1=0.995$] (Table 5). Pretest scores [$M=56$; $SD=28.9$] were lower than posttest 2 [$M=61.8$; $SD=29.9$; $p=0.002$; IC95%: -9.4, -2.2]. Likewise, posttest 1 scores [$M=58.7$; $SD=30.9$] were lower than posttest 2 [$p=0.013$; IC95%: -5.6, -0.6]. No significant differences were found between pretest and posttest 1 [$p=0.078$] (**Table 6**).

Furthermore, statistically significant differences were found in balance measures (Pediatric Berg Scale, 0–100), with a moderate effect size [$F(1,28)=35.94$; $p<.001$; $\eta2=0.692$; $\beta\text{-}1=1$] (**Table 6**). Pretest scores [$M=59.1$; $SD=31.8$] were lower than posttest 1 [$M=64.6$; $SD=32.5$; $p<.001$; IC95%: -8.3, -2.7] and posttest 2 [$M=67$; $SD=31.9$; $p < .001$; IC95%: -11, -4.8]. Likewise, posttest 1 scores were lower than posttest 2 [$p<.001$; IC95%: -3.7, -1,1] (**Table 6**).

DISCUSSION

This study determined the effect of Halliwick aquatic therapy and a land-based homologous program on postural control in children with CP, providing relevant clinical evidence through a crossover design. Both interventions showed significant improvements in balance and gross motor function (walking, running, and jumping); however, only the land-based intervention demonstrated significant improvements in gross motor function (walking, running, and jumping). This finding is consistent with the review by tapia and colleagues, which discussed the effectiveness of different aquatic therapy approaches in improving motor function in children with CP, suggesting that although aquatic therapy offers benefits, land-based therapy may be more effective for certain gross motor skills.[24]

The difference between the two environments can be explained through motor learning theory and dynamic models of postural control.11,13 While water facilitates smoother and less painful movements due to mechanical properties such as buoyancy,[25-26] it may also limit the development of skills requiring antigravity effort.19 Conversely, land provides an environment more representative of the child's real functional demands, promoting greater transfer of skills to daily life activities.[17,27]

This difference can be explained by biological and neuromuscular mechanisms inherent to each environment. On land, the constant action of gravity requires greater activation of the antigravity and trunk-stabilizing musculature, strengthening the recruitment patterns necessary for locomotion and postural control.[28] Continuous contact with the ground also provides richer proprioceptive feedback, enhancing the development of anticipatory and reactive balance responses.[29] These adaptations enable a more efficient functional transfer to daily life activities that depend on coordinated intersegmental control.

Although buoyancy reduces mechanical load and muscle effort21, and hydrostatic pressure provides multidirectional sensory input, these same properties may limit extensor muscle activation and reduce proprioceptive challenge, especially during tasks requiring full weight-bearing, such as walking, running, and jumping.[17] Consequently, aquatic interventions may primarily benefit static and dynamic balance, rather than the development of high-demand locomotor functions that rely on gravitational resistance.

Although Halliwick aquatic therapy has demonstrated positive effects on parameters such as postural adjustment and balance, the results of this study suggest that the land-based homologous program, applying the principles of the method under full gravitational force, is more effective at improving motor function, with large effect sizes. This may be due to its ability to provide a solid and stable support surface for performing motor activities, facilitating the development of both gross and fine motor skills with greater functional demands.[20,30] This suggests that full gravity is an essential facilitating factor for training complex motor skills such as walking, running, and jumping.[8]

A relevant aspect of this study was that the sequential application of both therapies also produced significant improvements. This finding indicates that a mixed treatment of consecutive therapies, applying one intervention followed by the other, regardless of order (land-based homologous plus Halliwick, or Halliwick plus land-based homologous),31 is useful for improving balance and gross motor function (walking, running, and jumping) in children with CP aged 5 to 15 years classified as GMFCS levels I, II, and III, and should be considered in future clinical protocols.[29]

From a clinical and public health perspective, these results have important implications. The possibility of applying for a land-based program with outcomes comparable to or even superior to the aquatic method could represent a low-cost and highly accessible alternative, especially in regions with limited resources for aquatic infrastructure. Furthermore, the standardization of land-based homologous programs could facilitate professional training and the replicability of treatments.

A limitation of the study is the lack of statistical verification of the residual effect of the first intervention on postural control variables, which could affect the results of the second intervention. It is recommended to conduct multicenter studies with larger samples to evaluate the generalizability of the findings. Additionally, future research should include more diverse samples and explore the impact of combining different types of therapies to provide a holistic and personalized approach to the treatment of children with CP.

CONCLUSION

The land-based program, homologous to the therapeutic exercises developed with HAT, improved both balance and gross motor function related to walking, running, and jumping in children with CP aged 5 to 15 years classified as GMFCS levels I, II, and III. In contrast, the HAT intervention improved only balance.

No significant differences were found in the improvement of the balance between terrestrial and aquatic interventions in the sample studied. The LBHTP significantly improved gross motor function (walking, running, and jumping) more than HAT.

The combined treatment of consecutive therapies, applying one intervention followed by the other regardless of order (LBHTP or HAT), is useful for improving balance and gross motor function (walking, running, and jumping) in children with CP aged 5 to 15 years classified as GMFCS levels I, II, and III.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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ETHICAL CONSIDERATION

The study was approved by the Ethics, Bioethics, and Scientific Integrity Committee of the Universidad Autónoma de Manizales, Colombia, as recorded in Act No. 150 of May 10, 2023 (code 166-150).

AUTHOR CONTRIBUTIONS

All authors fully participated in every phase of the study: proposal and conceptualization, funding acquisition, data collection, statistical analysis, analysis and discussion of results, and drafting of the final report.

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