

# Efficacy of the comprehensive intervention model for children <6 years of age with spastic cerebral palsy

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**Abstract.** It is estimated that 30-40% of the disabilities in children are attributed to cerebral palsy, resulting in a marked psychological and economic burden for families and society. Early interventions and a comprehensive intervention model are recommended for young children with cerebral palsy; however, the effectiveness of this model in children with spastic cerebral palsy has yet to be studied. Therefore, the present study conducted an uncontrolled prospective study on 50 children aged <6 years with spastic cerebral palsy. A comprehensive, goal-oriented and family-centered rehabilitation model was developed, and participants received the intervention for 6 months from January, 2019 to December, 2022. Following the intervention period, 616/771 Goal Attainment Scaling goals in physical therapy, occupational therapy and speech therapy were achieved. The children exhibited a significant improvement in gross motor functions, mobility, self-care and social skills after 6 months ( $P<0.05$ ). The Gross Motor Function Classification System level and the type of paralysis were found to be associated with an improvement in the Gross Motor Function Measure (GMFM) 66 score ( $P<0.05$ ). There was positive correlation between the improvement of the Pediatric Evaluation of Disability Inventory (PEDI) mobility functional skills score and the GMFM 66 score ( $r=0.75$ ;  $P<0.001$ ), and the PEDI mobility functional skills score and the PEDI self-care functional skills score ( $r=0.55$ ;  $P<0.001$ ). On the whole, the present comprehensive, goal-directed and family-centered rehabilitation model effectively improved gross, mobility, self-care and social skills and perhaps it could be expanded to rehabilitation centers.

## Introduction

Cerebral palsy is defined as a group of permanent disorders of movement and posture development due to non-progressive brain damage during the fetal period or early childhood, thus causing limitations in activity. Motor disorders in cerebral palsy are often accompanied by sensory, perceptual, cognitive, communication, behavioral, epilepsy and secondary musculoskeletal issues (1). The global prevalence of cerebral palsy is 1.5-3/1,000 live births, with spastic cerebral palsy being the most common type, accounting for 72-80% of recorded cases (2-5). In Vietnam, it is estimated that ~500,000 individuals live with cerebral palsy, equivalent to 30-40% of the total disabilities in children (6). Cerebral palsy is the most common physical disability in children, often associated with lifelong multiple disabilities, rendering it a significant psychological and economic burden for families and societies worldwide (5).

Due to multiple disabilities, children with cerebral palsy require rehabilitation across various domains, although in particular, they require physical therapy, occupational therapy and speech therapy (5,7). Goal-oriented therapy methods designed based on motor learning theory and neural plasticity, which train tasks that are useful for daily life, have proven to be effective for children with cerebral palsy. Evidence-based practice is recommended for clinicians to use instead of traditional treatment methods (8).

The Goal Attainment Scale (GAS), Gross Motor Function Measure 66 (GMFM 66) and Pediatric Evaluation of Disability Inventory (PEDI) are widely recognized tools for assessing functional outcomes in pediatric populations, particularly in children with motor impairments. GAS is a patient-centered measure that evaluates individualized goal achievement, offering a personalized perspective on therapy outcomes (9-11). The GMFM 66 quantitatively assesses changes in gross motor function, particularly in children with cerebral palsy, providing a reliable measure of motor performance improvements (7). The PEDI evaluates functional capabilities and performance in daily activities, capturing a comprehensive view of the independence of a child and caregiver assistance needs (12,13). These tools collectively provide a robust framework for assessing the multidimensional impact of interventions.

Globally, a comprehensive intervention model for children with cerebral palsy has been established. With a

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family-centered approach, clinicians have collaborated to provide evidence-based practices that meet the diverse treatment needs of the children (14). In Vietnam, early detection and early intervention for young children aged <6 years with disabilities have been identified as key components of rehabilitation and community-based rehabilitation in recent years (15). Research has demonstrated the effectiveness of interventions based on motor learning theory and neuroplasticity for children with cerebral palsy (16). During development, the brains of children exhibit greater neuroplasticity potential compared with more mature brains, providing enhanced opportunities for therapeutic interventions (17). The Vietnam Ministry of Health has incorporated the requirements of the comprehensive rehabilitation model into the practice philosophy to guide the organization of the model and improve rehabilitation services for children with cerebral palsy (7,18-20). However, early intervention and comprehensive intervention models for young children with disabilities remain sporadically organized (15). Studies on cerebral palsy primarily focus on epidemiological and clinical characteristics or report outcomes of single rehabilitation methods rather than studying the effectiveness of a comprehensive goal-oriented and family-centered rehabilitation model (6,21). The successful implementation of a comprehensive, goal-directed, family-centered rehabilitation model for children aged <6 years with spastic cerebral palsy represents a significant advancement in both the theory and clinical practice of rehabilitation in Vietnam. This model has the potential for broad application across rehabilitation centers nationwide. Therefore, the present study aimed to fill the current gap by evaluating the simultaneous effectiveness of interventions in the three main rehabilitation areas: i) Physical therapy; ii) occupational therapy; and iii) speech therapy.

## Patients and methods

*Study design.* The present study was a prospective, non-randomized cohort study using a comprehensive intervention model developed as part of a rehabilitation training program provided by Humanity and Inclusion at Hanoi Rehabilitation Hospital (Hanoi, Vietnam) from January, 2019 to December, 2022.

*Study subjects.* Participants were children aged <6 years, who were diagnosed with spastic cerebral palsy and who received treatment at the Department of Pediatrics of Hanoi Rehabilitation Hospital. The inclusion criteria for the present study included a confirmed diagnosis of spastic cerebral palsy according to the National Institute for Health and Care Excellence and the Vietnam Ministry of Health guidelines, characterized by motor and postural disorders due to non-progressive brain damage that occurred before, during or after birth with increased muscle tone and tendon reflexes in affected limbs or signs of pyramidal tract damage (1,18,22,23). Participants were also required to be in level II, III or IV of the Gross Motor Function Classification System (GMFCS), level II, III or IV of the Manual Ability Classification System (MACS; Mini MACS) and level II, III or IV of the Communication Function Classification System (CFCS). The GMFCS classifies gross motor function, focusing on what children with cerebral palsy can achieve within their living and activity

environments (24). The MACS (for ages 4-18 years) and Mini-MACS (for ages 1-4 years) classify the ability of children with cerebral palsy to use their hands to manipulate objects in daily activities (25). The CFCS categorizes children with cerebral palsy into 5 levels based on their daily communication abilities, considering 3 factors: i) The ability to receive and send messages; ii) the pace of communication with familiar or unfamiliar individuals; and iii) communication methods such as speech, sound, eye gaze, facial expressions, gestures, symbols, books, communication boards or assistive devices (25). Children with hearing impairment or vision loss and those who either discontinued or failed to comply with treatment protocols were excluded from the present study. Participation was voluntary and written informed consent from the children's guardians was obtained.

*Ethical considerations.* The present study was approved by The Ethics Committee of Hanoi Medical University (approval no: 60/HĐĐĐHYHN; Hanoi, Vietnam). The present study was conducted with the voluntary consent of the participants' guardians and research subjects could withdraw from the present study at any stage. All information obtained was used solely for research purposes.

*Measurement of outcomes.* *GAS* (9-11,18). The GAS is a 5-level goal scale in which a score of -2 represents the condition of the child at the start of the intervention and a score of 0 corresponds to the expected outcome after the intervention. The interpretation of each level is presented in Table I.

*GMFM 66* (7). The GMFM 66 measures gross motor function in children with cerebral palsy and includes 66 items covering five domains: i) Lying and rolling (four items); ii) sitting (15 items); iii) crawling and kneeling (10 items); iv) standing (13 items); and v) walking, running and jumping (24 items). The GMFM 66 reference percentile was analyzed from a normal sample of 650 children with cerebral palsy (24). Higher GMFM scores indicate greater motor abilities and improved functional performance.

*PEDI* (12,13). The PEDI measures the performance of a child in everyday activities, administering two parts of the rating scale including functional skills (FS) and caregiver assistance (CA), and assessed the following 3 areas: i) Self-care; ii) mobility; and iii) social function. The PEDI was completed by interviewing the primary caregiver of the child. The raw score was calculated and transformed into a scale score. Higher scores reflect greater independence and reduced need for caregiver assistance, showing improvement in daily living activities and overall functional skills.

*Comprehensive, goal-oriented and family-centered rehabilitation model.* The development of the model consisted of the following four steps:

Step 1: Orienting goals based on the needs of the family: Upon admitting a child with cerebral palsy to the hospital, the family of the child was provided with information about cerebral palsy, the treatment model and evidence-based practices that were suitable for the child and available at the hospital. Subsequently, the family underwent an in-depth interview with

Table I. GAS scoring.

GAS score	Levels of achievement
-2	Much less than expected outcome
-1	Less than expected outcome
0	Expected outcome after intervention
+1	More than expected outcome
+2	Much more than expected outcome

GAS, Goal Attainment Scale.

a clinician, which focused on discussions between the clinician and the family to understand their goals and expectations when bringing the child to the hospital. Following the interview, the clinician helped the family to prioritize these goals for the treatment plan. After which, the clinician performed the PEDI and collaborated with the family to establish the intervention goals.

**Step 2: Setting GAS goals based on a consensus between clinicians and the family:** Clinicians carried out necessary evaluations to support the establishment of specific GAS goals. After these assessments, the clinicians formulated the GAS goals and discussed the assessment results with the family. This step involved an agreement with the family to ensure that the GAS goals align with their expectations and the needs of the child.

**Step 3: Planning and conducting the intervention:** An intervention plan detailing training activities, time allocated for these activities and the roles of clinicians and family in the intervention was developed. The clinicians performed therapy sessions with the child at the hospital and guided the family on conducting the exercises at home.

**Step 4: Post-intervention evaluation:** Following the intervention, the clinicians and the family evaluated the achievement of the GAS goals together. The clinicians then reassessed the child and provided the family with detailed feedback on the assessment results and progress.

Key members of the clinician team included a rehabilitation doctor, physical therapist, occupational therapist and speech therapist. Additional members, such as a pediatrician or orthodontist, would be included depending on the condition of the child. The rehabilitation doctor acted as the team leader, overseeing all information related to the child, performing the PEDI by interviewing the primary caregiver of the child, orienting the intervention goals with the family and re-evaluating the achievement of the GAS goals after the intervention. Team members exchanged information on a weekly basis throughout the implementation process.

**Intervention.** Children received therapy at the hospital 5 days/week, 3 weeks/month for 6 months. Each session lasted 1.5 h and included physical therapy (30 min), occupational therapy (30 min) and speech therapy (30 min).

Physical therapy focused on improving gross motor skills and mobility. Occupational therapy aimed to enhance fine motor skills and self-care abilities. Speech therapy was targeted

at developing communication and social skills. Goal-directed therapy techniques were applied, which involved practicing specific activities based on goals co-designed with the patient. Based on the principles of motor learning and neuroplasticity, this therapy emphasizes active and repetitive practice of tasks in real-life environments or similar simulated settings. Individualized speech therapy complements this by focusing on developing early communication skills and enhancing the ability to understand and express language.

Caregivers carried out at-home exercises according to the guidance of clinicians, and children were encouraged to involve themselves in the targeted activities as much as possible. The length of home exercises varied based on the number and content of intervention goals. Physical therapy typically lasted 30-60 min/day as guided by the physical therapist. Occupational therapy included simulated play activities with encouragement to engage in targeted activities, and speech therapy focused on achieving intervention goals during daily communication activities.

**Data collection.** The research process is presented in Fig. 1. Children with cerebral palsy who met the inclusion criteria underwent a comprehensive clinical examination. This included interviewing their parents or primary caregivers to gather information on the medical history and condition of the child following the research case report template. GMFCS, MACS/MiniMACS and CFCS levels were also assessed.

The PEDI and GMFM 66 scale were assessed at three time points: i) Before the intervention (T0); ii) after 3 months (T1); and iii) after 6 months (T2). The GAS scale criteria, established by the clinicians, were evaluated after 6 months, with the goal achievement results assessed in collaboration with the families of the children with cerebral palsy (Fig. 1).

**Statistical analysis.** Data entry and analysis were performed using STATA 15.0 software (StataCorp LLC). The Shapiro-Wilk test was used to test for normality. The Kruskal-Wallis test was used to compare the differences in intervention results between T0, T1 and T2, followed by Dunn's test with Bonferroni correction. Spearman's rank correlation test was used to analyze the correlation between variables. Linear regression was used to identify factors related to treatment outcomes.  $P \leq 0.05$  was considered to indicate a statistically significant difference.

**Results**

The demographic and clinical characteristics of the 50 children participating in the present study are presented in Table II. Among these children, 60% had spastic quadriplegia, 26% had spastic hemiplegia and 14% had spastic diplegia. The boy-to-girl ratio was 1.94:1, with boys accounting for 66% of the participants. The average age of the participants was 39.34 months, with the highest percentage (50%) being 24-47 months.

As regards gross motor function, 34% of the children were classified as GMFCS level II, 40% as level III and 26% as level IV. Notably, 43.3% of the children with quadriplegia were in GMFCS level IV, while none of the children with spastic diplegia or hemiplegia were at this level.

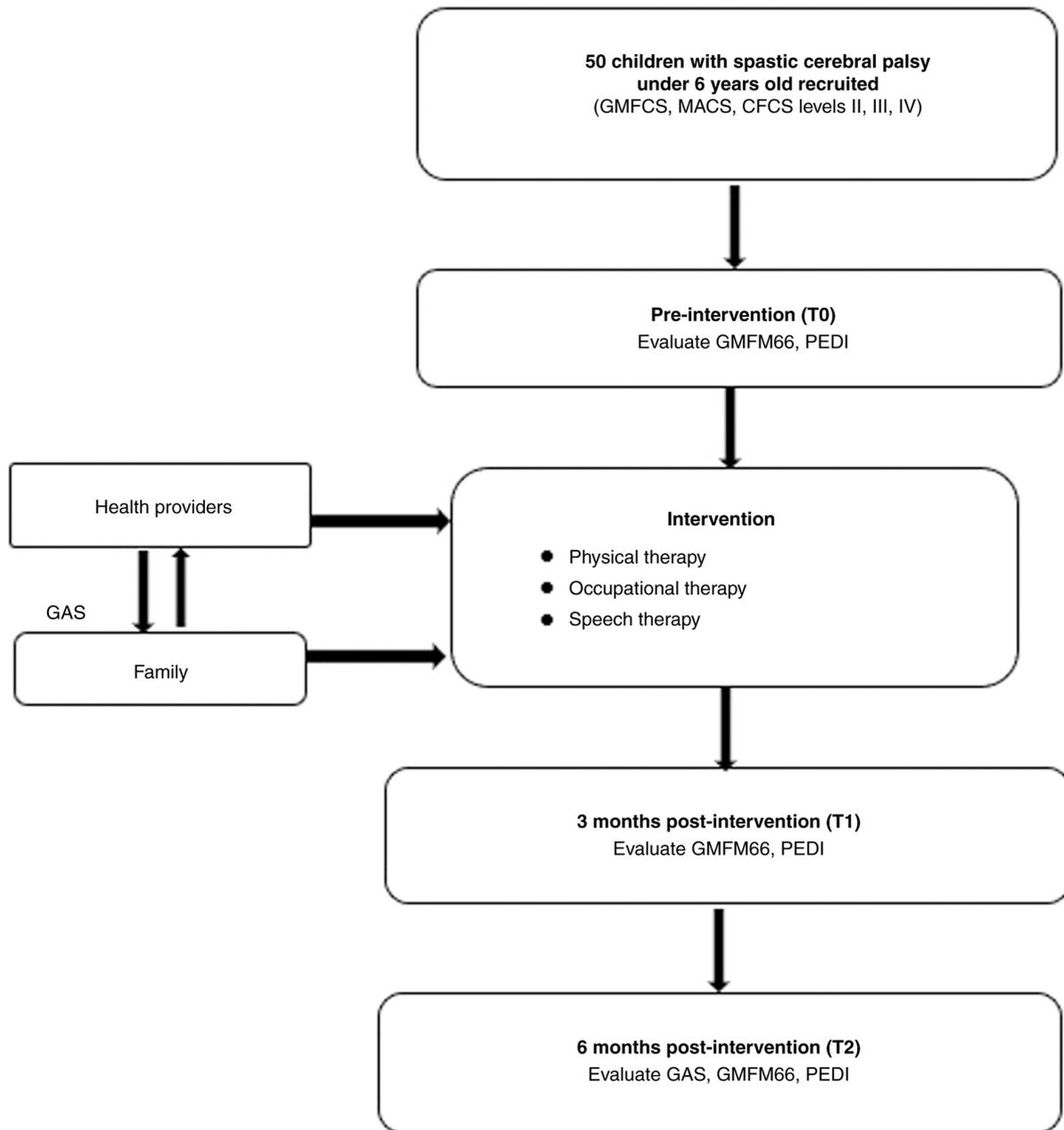


Figure 1. Flowchart of the research process in the present study. GMFM, Gross Motor Function Measure; MACS, Manual Ability Classification System; CFCS, Communication Function Classification System; GMFM, Gross Motor Function Measure; PEDI, Pediatric Evaluation of Disability Inventory.

The MACS (Mini MACS) evaluation of hand use revealed that 32% of the children were in level II, 46% in level III and 22% in level IV. No children with hemiplegia were categorized in level IV and 100% of those with diplegia were at MACS level II.

As regards communication function, 28% had CFCS level II, 40% had level III and 32% had level IV. Among those with quadriplegia, 50% were at CFCS level IV, while 61.5% of children with hemiplegia were at level III and 86.7% of spastic diplegia cases were at level II (Table II).

A total of 522 GAS goals were established for physical therapy and occupational therapy over the 6-month period of rehabilitation. The achievement rate for physical therapy goals (levels 0, 1 and 2) was 81.3%, while the achievement rate for occupational therapy goals was 82.7%. The combined

achievement rate for physical and occupational therapy goals was 100%. As regards speech therapy, 249 GAS goals were established and 74.7% of the children achieved the goals (Table III).

The treatment results after 3 months and 6 months of intervention are presented in Table IV. The GMFM 66 score increased by 4.9 points at T1 ( $P=0.09$ ) and 9.9 points at T2 ( $P<0.001$ ). The GMFM 66 reference percentile rose by 17.1 points and 31.1 points after 3 and 6 months, respectively. Increases of 5.6 points (T1) and 11.0 points (T2) were observed in the PEDI FS mobility. The PEDI CA mobility was improved by 7.0 and 12.9 points at T1 and T2, respectively. The PEDI FS self-care exhibited a gain of 4.7 points following 3 months of rehabilitation and 8.8 points after 6 months. PEDI CA self-care increased by 7.2 points

Table II. Characteristics of the study participants (n=50).

Characteristics	Site of paralysis			Total, n (%)
	Quadriplegia, n (%)	Hemiplegia, n (%)	Diplegia, n (%)	
<b>Sex</b>				
Boys	21 (70.0)	7 (53.9)	5 (71.4)	33 (66.0)
Girls	9 (30.0)	6 (46.2)	2 (28.6)	17 (34.0)
<b>Age</b>				
≤23 months	7 (23.4)	2 (15.4)	0	9 (18.0)
24-47 months	13 (43.3)	9 (69.2)	3 (42.9)	25 (50.0)
48-71 months	10 (33.3)	2 (15.4)	4 (57.1)	16 (32.0)
<b>GMFCS</b>				
II	4 (13.4)	10 (76.9)	3 (42.9)	17 (34.0)
III	13 (43.3)	3 (23.1)	4 (57.1)	20 (40.0)
IV	13 (43.3)	0	0	13 (26.0)
<b>Mini MACS</b>				
II	1 (3.3)	8 (76.9)	7 (100.0)	16 (32.0)
III	18 (60.0)	5 (23.1)	0	23 (46.0)
IV	11 (36.7)	0	0	11 (22.0)
<b>CFCS</b>				
II	4 (13.3)	4 (30.7)	6 (86.7)	14 (28.0)
III	11 (36.7)	8 (61.5)	1 (14.3)	20 (40.0)
IV	15 (50.0)	1 (7.7)	0	16 (32.0)

GMFCS, Gross Motor Function Classification System; MACS, Manual Ability Classification System; CFCS, Communication Function Classification System.

Table III. Results of achieving GAS goals in physical therapy and occupational therapy after 6 months of rehabilitation.

Area	GAS score					Total, n (%)
	-2 n, (%)	-1 n, (%)	0 n, (%)	1 n, (%)	2 n, (%)	
Physical therapy	15 (5.6)	35 (13.1)	120 (44.9)	61 (22.9)	36 (13.5)	267 (100)
Occupational therapy	8 (3.3)	34 (14.0)	114 (46.9)	51 (21.0)	36 (14.8)	243 (100)
Physical and occupational	0 (0)	0 (0)	6 (50)	5 (41.7)	1 (8.3)	12 (100)
Speech therapy	18 (7.2)	45 (18.1)	95 (38.2)	58 (23.3)	33 (13.2)	249 (100)

GAS, Goal Attainment Scale.

at the 3-month assessment and 13.0 points at 6 months. All differences observed were statistically significant ( $P \leq 0.05$ ). Similarly, the PEDI FS social function increased by 5.7 points at T1 and 11.1 points at T2. These improvements were statistically significant. The PEDI CA social function also showed significant gains, increasing by 7.9 points after 3 months and 14.8 points after 6 months ( $P \leq 0.01$ ).

The results of the multivariable linear regression model underscored that the site of paralysis and GMFCS levels are significant predictors of GMFM 66 score improvements, whereas sex, age and other classifications are insignificantly associated with the outcome (Table V). Compared with

children with spastic quadriplegic cerebral palsy, those with hemiplegia showed a significantly greater improvement in GMFM 66 scores (Coef.=1.45;  $P=0.03$ ). GMFCS levels also significantly affected GMFM 66 score improvement. In comparison with children classified as GMFCS level II, those at GMFCS level III presented a 1.37-point lower improvement in GMFM 66 scores ( $P=0.01$ ), while children at GMFCS level IV had a 3.97-point lower improvement ( $P < 0.001$ ).

There was a strong positive correlation between the improvement in GMFM 66 scores and the improvement in PEDI FS mobility scores after 6 months of rehabilitation ( $P < 0.001$ ), suggesting the improvement of PEDI FS mobility

Table IV. Results of the intervention (n=50).

	T0 (mean ± SD)	T1 (mean ± SD)	T2 (mean ± SD)	Pairwise comparison	Mean difference	95% CI	P-value
GMFM 66	44.7±12.9	49.7±13.9	54.7±14.6	T1-T0	4.9	4.5-5.3	0.09
				T2-T0	9.9	9.3-10.6	<0.001
GMFM 66 reference percentile	43.52±31.0	60.60±33.4	74.60±29.0	T1-T0	17.1	14.5-19.7	0.008
				T2-T0	31.1	26.2-35.9	<0.001
PEDI FS mobility	41.4±11.7	47.1±12.4	52.5±13.0	T1-T0	5.6	5.3-5.9	0.04
				T2-T0	11.0	10.5-11.6	<0.001
PEDI CA mobility	37.9±12.3	44.9±12.2	50.8 ±13.1	T1-T0	7.0	6.4-7.5	0.01
				T2-T0	12.9	12.2-13.5	<0.001
PEDI FS self-care	39.2±10.4	43.9±11.0	48.0±11.8	T1-T0	4.7	4.5-5.0	0.05
				T2-T0	8.8	8.0-9.6	0.03
PEDI CA self-care	31.0±14.1	38.2±13.5	44.0±13.4	T1-T0	7.2	6.7-7.7	<0.001
				T2-T0	13.0	12.3-13.8	<0.001
PEDI FS social function	40.5±9.2	46.2±9.7	51.6±10.5	T1-T0	5.7	5.4-6.0	0.01
				T2-T0	11.1	10.4-11.8	<0.001
PEDI CA social function	34.3±12.0	42.2±11.6	49.1±11.8	T1-T0	7.9	7.3-8.4	0.006
				T2-T0	14.8	14.0-15.6	<0.001

GMFM, Gross Motor Function Measure; PEDI FS, Pediatric Evaluation of Disability Inventory Functional Skills; PEDI CA, PEDI Caregiver Assistance; CI, confidence interval.

Table V. Association between age, sex, site of paralysis, GMFCS level, MACS level and CFCS level, and the improvement in GMFM 66 scores after six months of rehabilitation.

Parameters	Coef.	P-value	95% CI	
Age, months	0.02	0.28	-0.01	0.05
Sex (in reference to boys)				
Girls	0.04	0.91	-0.77	0.86
Site of paralysis (in reference to quadriplegia)				
Hemiplegia	1.45	0.03	0.18	2.72
Diplegia	0.59	0.52	-1.22	2.40
GMFCS levels (in reference to level II)				
Level III	-1.37	0.01	-2.35	-0.39
Level IV	-3.97	<0.001	-5.41	-2.53
MACS levels (in reference to level II)				
Level III	-0.47	0.47	-1.75	0.82
Level IV	-0.23	0.78	-1.88	1.42
CFCS levels (in reference to level II)				
Level III	0.24	0.65	-0.82	1.31
Level IV	0.44	0.50	-0.88	1.76

GMFCS, Gross Motor Function Classification System; MACS, Manual Ability Classification System; CFCS, Communication Function Classification System; GMFM, Gross Motor Function Measure; Coef., coefficient; CI, confidence interval.

scores as GMFM 66 scores increased. Additionally, there was a moderate positive correlation ( $r=0.55$ ) between the improvement in PEDI FS mobility scores and PEDI FS self-care scores ( $P<0.001$ ), implying that improvements in mobility skills are associated with enhancements in self-care abilities (Fig. 2).

## Discussion

As regards physical therapy and occupational therapy, the results of achieving GAS goals in the present study were similar to the results presented in the study by Storvold and

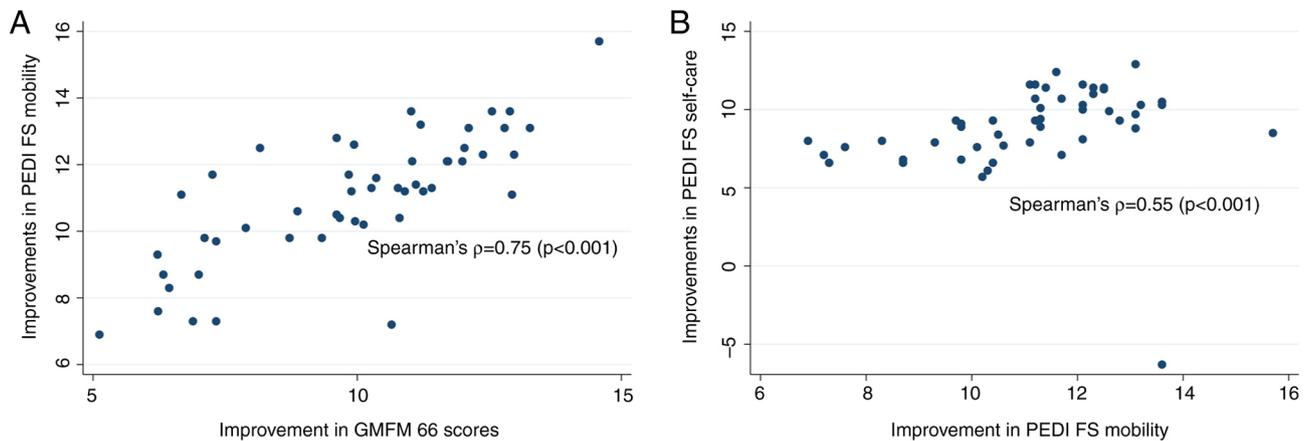


Figure 2. Correlation between (A) the improvement in the GMFM 66 scores and the improvement in PEDI FS mobility after 6 months of rehabilitation; (B) the improvement in the PEDI FS mobility and the improvement in PEDI FS self-care after 6 months of rehabilitation.

Jahnsen (27) (82.86%) and Lowing *et al* (26) (84.55%) in terms of mobility and self-care goals. In the present study, several goals of coordination between physical therapy and occupational therapy were established. The role of teamwork in the rehabilitation process for children with cerebral palsy has been promoted to achieve the desired goals of the child and family. To ensure the validity and reliability of the GAS, all healthcare staff who directly interacted with the children had >1 year of experience and were trained in a GAS goal setting. Therapists worked with families to establish GAS goals, while rehabilitation doctors evaluated standard scales and collaborated with families to assess the achievement of these goals.

An intensive intervention program (>3 sessions/week), including goal-directed therapy, has been shown to effectively improve gross motor function in children with cerebral palsy (27-31). The GMFM 66 results from the present study are lower than the study by Storvold and Jahnsen (27) where a 6-week, 5 days/week and 10 h/week, intervention at the rehabilitation center combined with home and school exercises increased GMFM 66 scores by 10.79 points for children with GMFCS levels I and II (27). Similarly, Sorsdahl *et al* (32) reported a 4.5-point increase after a 3-week, 5 days/week and 3 h/day intervention for children with GMFCS levels I-IV (32). These differences may be attributed to variations in participant selection and intervention intensity, as the present study selected children with more severe GMFCS (levels II, III and IV) and possibly lower intervention dosage compared with the other studies. By contrast, Lowing *et al* (26) reported an increase of 5.02 points after 3 months of intervention for 22 children with GMFCS levels I-IV, and are higher compared with the study by Ahl *et al* (30) who found a 3.13-point increase after 5 months of goal-directed therapy for 14 children with GMFCS levels II-V (26,30). In both studies, children exercised at the center once/week and the remainder of the time at home.

Overall, studies on goal-directed therapy show that children with cerebral palsy were all actively engaged in treatment >3 times/week. The specific intervention dosage and whether the intervention is conducted by healthcare professionals or the primary caregivers of the child with cerebral palsy may vary depending on the study. The results of these studies demonstrate that children with cerebral palsy exhibit improvements

following intervention. However, the level of progress appears to be influenced by the treatment dosage. Higher dosage treatments, such as in the studies by Storvold and Jahnsen (27) and Sorsdahl *et al* (32) are more likely to record improved progress. Additionally, the GMFCS level may also be related to treatment effectiveness.

In studies on the effectiveness of goal-directed therapy and comparing GMFM 66 scores, studies without control groups also use the GMFM 66 reference percentile. The GMFM 66 reference percentile helps to assess the relative motor ability of the study subjects compared with children with cerebral palsy of the same age and GMFCS level. An increase in the GMFM 66 reference percentile score following intervention indicates that the child has made significant progress in gross motor function following the intervention, as their progress surpasses that of the standard sample. In the present study, at T1 and T2, all children showed an increase in the GMFM 66 reference percentile scores compared with T0. Additionally, after 3 months of intervention, the reference percentile scores increased by an average of 17.1 points, and after 6 months, they increased by 31.1 points. The present study results are consistent with Lowing *et al* (26) where the GMFM 66 reference percentile score increased by 18 points after 3 months, and Storvold and Jahnsen (27) in which the GMFM 66 reference percentile scores increased from 15 to 37 points after 6 weeks.

The results of the present study are similar to those of the study by Sorsdahl *et al* (32) who found that the GMFM 66 score of children with cerebral palsy GMFCS levels I and II improved more than levels III, IV and V after 3 weeks of intervention. However, the current results are different from Lowing *et al* (26) which reported that after 3 months of rehabilitation, the gross motor ability of children with cerebral palsy improved but did not correlate to the level of GMFCS. Considering the site of paralysis, the present findings are also similar to the research results of Storvold and Jahnsen (27) where children with spastic quadriplegia showed less improvement in GMFM 66 scores compared with children with spastic hemiparesis.

The improvement of the PEDI FS mobility scores in the present study is similar to the results of the study by Lowing *et al* (26), which reported an increase of 5.85 points in

PEDI FS mobility after 3 months of intervention. However, the improvement in PEDI CA mobility was 9.4 points, higher than the results of the present study.

The improvement of the PEDI FS self-care of children with cerebral palsy in the present study is similar to the research results of Ahl *et al* (30) and Lowing *et al* (26) after 3 months, however, they reported a higher level of improvement in the PEDI level of assistance in self-care skills, at 10.99 points. These differences may be because in Vietnam, families typically help children with cerebral palsy more in mobility and self-care activities.

While the GMFM 66 measures gross motor function, it does not capture how these abilities translate into functional mobility in daily life, such as moving on a bed, using a wheelchair, navigating indoors or moving outdoors (28). Therefore, to evaluate the effectiveness of goal-directed therapy, where goals are tied to specific and practical daily activities, researchers often combine the GMFM 66, PEDI mobility domain and the GAS scores (27,32). By combining different assessment tools, a comprehensive understanding of the motor and mobility capabilities of the child in the therapy room, at home and in the community can be assessed, thus providing a holistic evaluation of the effectiveness of goal-directed therapy for children with cerebral palsy.

Han *et al* (33) found a strong correlation ( $r=0.83$ ) between the GMFM 66 and PEDI FS mobility scores in children with spastic cerebral palsy aged 1-6 years, which aligns with the findings of the present study (33). In the present study, a greater improvement in GMFM-66 scores was associated with higher improvement in PEDI FS mobility.

Improvements in PEDI FS mobility and PEDI FS self-care are positively correlated ( $r=0.55$ ;  $P<0.001$ ). This result indicates that in a rehabilitation model combining physical and occupational therapy, children with cerebral palsy tend to make simultaneous progress in both mobility and self-care skills.

As regards speech therapy, 249 GAS goals were established and 74.7% of the children achieved the goals. The PEDI FS social function and PEDI CA social function in the present study at the 3-month mark improved more than the research results of Sorsdahl *et al* (32), Lowing *et al* (26) and Ahl *et al* (30). This may be because the participants in the present study received goal-directed physiotherapy, occupational therapy and speech therapy simultaneously.

The findings of the present study have some implications for clinical practice and future research. Rehabilitation centers should implement a comprehensive, goal-directed and family-centered rehabilitation model for children with cerebral palsy. Additionally, further research is required to assess how family training programs affect the knowledge, attitudes and practices of guardians. Based on these evaluations, treatment programs can be developed to enhance the duration of home-based practice while reducing the time spent in hospital-based therapy.

The results of the present study should be considered in light of several limitations. First, a control group or pre-intervention follow-up were not included, which means that the natural progression of functional development over time could not be entirely ruled out as a factor influencing the observed improvements in children with cerebral palsy.

In addition, the study did not comprehensively assess co-existing health issues, such as intellectual disabilities and speech difficulties, which could affect the ability of children to learn motor skills and communicate effectively. Another limitation is that the present study mainly evaluated the functional improvement of children with cerebral palsy after intervention in each area, and thus the association between the effectiveness of intervention methods in the comprehensive intervention model has not been analyzed in-depth. It should also be noted that implementing a comprehensive intervention model requires time and resources, such as developing an information system on cerebral palsy to provide to families and creating tools to simulate real-life activities. Rehabilitation centers in Vietnam are still facing a shortage of personnel, especially in the areas of occupational therapy and speech therapy (19,20). Therefore, it is essential to strengthen workforce training, conduct workshops and expand the model.

In conclusion, the comprehensive, goal-directed and family-centered rehabilitation model is effective for children <6 years old with spastic cerebral palsy.

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#### **Availability of data and materials**

The data generated in the present study may be requested from the corresponding author.

#### **Authors' contributions**

KCH and VMP conceived and designed the study, performed statistical analysis and interpretation of the data, were involved in the investigative aspects of the study, and wrote, reviewed and edited the manuscript. Both authors read and approved the final version of the manuscript. KCH and VMP confirm the authenticity of all the raw data.

#### **Ethics approval and consent to participate**

The present study was approved by The Ethics Committee of Hanoi Medical University (approval no.: 60/HĐĐĐHYHN; Hanoi, Vietnam). The research was conducted with the voluntary consent of the participants' guardians. Research subjects could withdraw from the study at any stage and all information obtained was used solely for research purposes.

#### **Patient consent for publication**

Not applicable.

#### **Competing interests**

The authors declare that they have no competing interests.

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