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Original Article

Effect of Task-Specific Training versus Neurodevelopmental Therapy on Balance, Postural Control, and Functional Independence in Children with Spastic Cerebral Palsy: A Randomized Controlled Trial

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ABSTRACT

Background: Children with spastic cerebral palsy commonly experience impaired balance, postural control, and functional independence. Task-Specific Training (TST) emphasizes repetitive practice of functional activities, whereas Neurodevelopmental Therapy (NDT) uses therapist-guided facilitation of posture and movement. Objective: To compare the effects of TST and NDT on balance, postural control, and functional independence in children with spastic cerebral palsy. Methods: This parallel-group randomized controlled trial included 40 children aged 5–12 years with GMFCS levels I–III, allocated equally to TST or NDT. Both groups received 30-minute sessions three times weekly for six weeks. Outcomes were assessed using the Pediatric Balance Scale (PBS), Trunk Control Measurement Scale (TCMS), and Wee Functional Independence Measure (WeeFIM). Paired- and independent-samples t-tests were used. Results: Both groups demonstrated significant within-group improvements in all outcomes ($p < 0.001$). At six weeks, TST produced higher post-intervention scores than NDT for PBS (48.20 ± 3.41 vs 43.10 ± 3.86; mean difference 5.10, 95% CI 2.77–7.43), TCMS (50.85 ± 4.08 vs 45.25 ± 4.47; mean difference 5.60, 95% CI 2.86–8.34), and WeeFIM (101.70 ± 5.81 vs 92.45 ± 6.36; mean difference 9.25, 95% CI 5.35–13.15), all $p < 0.001$. Conclusion: Both interventions were associated with improvement, while TST resulted in higher six-week balance, postural-control, and functional-independence scores than NDT. Keywords: Cerebral palsy; Task-Specific Training; Neurodevelopmental Therapy; Balance; Postural control; Functional independence; Pediatric Balance Scale; Randomized controlled trial.

INTRODUCTION

Cerebral palsy (CP) comprises a group of permanent disorders of movement and posture resulting from disturbances in the developing fetal or infant brain. Although the underlying neurological lesion is non-progressive, its functional manifestations may change across childhood as growth, muscle weakness, altered muscle tone, secondary musculoskeletal adaptations, and limitations in selective motor control interact to influence mobility and participation. Children with CP therefore commonly experience impairments in balance, postural stability, coordination, gait, transfers, and performance of activities of daily living, making rehabilitation an important component of long-term management (1).

Spastic cerebral palsy is characterized by increased muscle tone together with varying degrees of muscle weakness, impaired selective motor control, restricted range of motion, and abnormal movement strategies. These impairments can compromise the ability to maintain the body's center of mass within the base of support and to generate effective anticipatory and reactive postural responses during functional activity. Trunk dysfunction is particularly relevant because adequate proximal stability is required for coordinated upper- and lower-extremity movement, weight shifting, reaching, transfers, standing, and walking. Interventions directed toward trunk control and postural stability have consequently been associated with improvements in gross motor function and balance in children with CP (2).

Balance and postural control are closely related to functional independence. Difficulties maintaining alignment or adapting posture during movement may restrict sit-to-stand transfers, stair negotiation, walking, reaching, self-care, and other daily activities. Rehabilitation strategies that repeatedly expose children to meaningful functional challenges may therefore provide benefits extending beyond impairment-level outcomes to participation in everyday tasks. Evidence from systematic review and meta-analysis indicates that task-oriented training can improve gross motor function, balance, and activities of daily living in children with CP, although intervention protocols and treatment intensity vary considerably between studies (3).

Task-Specific Training (TST) is based on repeated practice of goal-directed activities that resemble tasks encountered in everyday life. Examples include sit-to-stand transfers, stepping, walking, obstacle negotiation, reaching, stair climbing, weight shifting, and balance activities. Repetition, active problem solving, feedback, task progression, and practice within meaningful contexts are central principles of motor learning and provide opportunities for children to refine movement strategies through experience. Reviews focusing specifically on task-related balance interventions suggest that task-specific approaches can produce clinically relevant improvements in functional balance in children with CP (4). Comparative clinical studies have likewise reported improvements in motor function and balance when task-oriented approaches are incorporated into pediatric physiotherapy programs (5).

Neurodevelopmental Therapy (NDT), commonly associated with the Bobath concept, remains widely used in pediatric neurorehabilitation. NDT emphasizes facilitation of more efficient movement strategies, postural alignment, trunk control, weight transfer, and management of atypical movement patterns through therapist-guided handling and functional activities. However, contemporary evidence has questioned whether NDT provides superior outcomes when compared with interventions characterized by active, intensive, task-specific practice. A meta-analysis evaluating NDT for cerebral palsy found limited evidence supporting its superiority over alternative approaches, highlighting the importance of comparing facilitation-based treatment with interventions involving greater amounts of active functional practice (1). More recent clinical evidence nevertheless suggests that NDT may improve gross motor function and activities of daily living, indicating that its effects should be assessed comparatively rather than regarded as absent (6).

The increasing emphasis on activity-based rehabilitation has strengthened interest in interventions that directly practice functional goals. Randomized evidence has demonstrated that task-specific training can facilitate acquisition of functional skills when training is closely matched to the activity being learned, reinforcing the principle of task specificity in children with CP (7). Nevertheless, differences among previous studies in cerebral palsy subtype, functional severity, intervention content, training intensity, treatment duration, and selected outcome measures make it difficult to determine whether task-specific practice consistently provides greater benefit than NDT across multiple clinically relevant domains. In particular, direct comparisons incorporating balance, trunk-related postural control, and functional independence within the same trial remain clinically relevant because these domains collectively influence mobility and participation.

Accordingly, the present study aimed to compare the effects of Task-Specific Training and Neurodevelopmental Therapy on balance, postural control, and functional independence in children with spastic cerebral palsy. It was hypothesized that children receiving Task-Specific Training would demonstrate greater improvement in Pediatric Balance Scale, Trunk Control Measurement Scale, and Wee Functional Independence Measure outcomes after six weeks of intervention than children receiving Neurodevelopmental Therapy.

MATERIALS AND METHODS

A prospective, parallel-group randomized controlled trial was conducted in 40 children with spastic cerebral palsy. Participants were recruited using convenience sampling and subsequently allocated to two treatment groups of equal size, with 20 children receiving Task-Specific Training and 20 receiving Neurodevelopmental Therapy. Eligible participants were 5–12 years of age, had a diagnosis of spastic cerebral palsy, were classified within Gross Motor Function Classification System (GMFCS) levels I–III, could understand and follow simple verbal commands, and were able to participate in a structured physiotherapy program. The GMFCS is a five-level classification system developed to categorize gross motor function in children with cerebral palsy according to functional abilities and limitations in sitting, transfers, and mobility (8).

Children were excluded if they had uncontrolled epilepsy, a history of orthopedic surgery or botulinum toxin injection during the preceding six months, severe visual or hearing impairment affecting participation or assessment, fixed musculoskeletal deformities that restricted performance of the intervention activities, or an additional neurological disorder affecting motor function. Forty participants completed the six-week intervention and post-intervention assessment, and all were included in the reported analysis.

Participants assigned to the Task-Specific Training group received 30-minute treatment sessions three times per week for six weeks. Training consisted of repeated practice of functional motor activities including sit-to-stand transfers, stair climbing, obstacle walking, balance-beam walking, standing reaching activities, step-up and step-down exercises, weight-shifting exercises, and functional walking tasks. These activities were selected to provide repeated practice of balance, postural adjustment, transitional movements, and functional mobility within task-oriented contexts. Evidence from pediatric CP research supports the use of repetitive task-oriented activity for improving balance and gross motor function (3–5,7).

Participants assigned to the Neurodevelopmental Therapy group received treatment of identical session duration and frequency: 30 minutes per session, three times weekly for six weeks. The NDT program incorporated trunk facilitation, postural-alignment activities, weight-shifting exercises, approaches directed toward management of abnormal muscle tone, balance facilitation, transitional movement practice, gait facilitation, and positioning. The intervention therefore emphasized therapist-guided facilitation of postural control and movement quality. NDT remains an established rehabilitation approach for children with CP, although evidence regarding its comparative effectiveness relative to active task-oriented interventions remains mixed (1,6).

The principal outcomes were balance, postural control, and functional independence. Outcomes were assessed before initiation of treatment and again at completion of the six-week intervention by an independent evaluator. Functional balance was evaluated using the Pediatric Balance Scale (PBS). The PBS is a pediatric adaptation of functional balance assessment and has demonstrated high inter-rater, intra-rater, and test-retest reliability in children with cerebral palsy (9).

Postural control was evaluated using the Trunk Control Measurement Scale (TCMS). The TCMS was developed specifically to evaluate trunk control in children with cerebral palsy and assesses clinically

relevant components of static and dynamic trunk performance. It has demonstrated acceptable validity and high reliability for assessment of trunk control in this population (10).

Functional independence was assessed using the Functional Independence Measure for Children (WeeFIM). The WeeFIM evaluates functional performance across self-care, mobility, and cognitive domains and has demonstrated strong reliability and validity in children with cerebral palsy (11). The same three outcome instruments—PBS, TCMS, and WeeFIM—were used at baseline and at the end of the six-week intervention period.

Data were analysed using IBM SPSS Statistics version 26.0. Continuous variables were summarized as mean and standard deviation, while categorical variables were reported as frequencies and percentages. Baseline continuous characteristics were compared between groups using independent-samples t-tests, whereas categorical baseline characteristics were compared using the chi-square test.

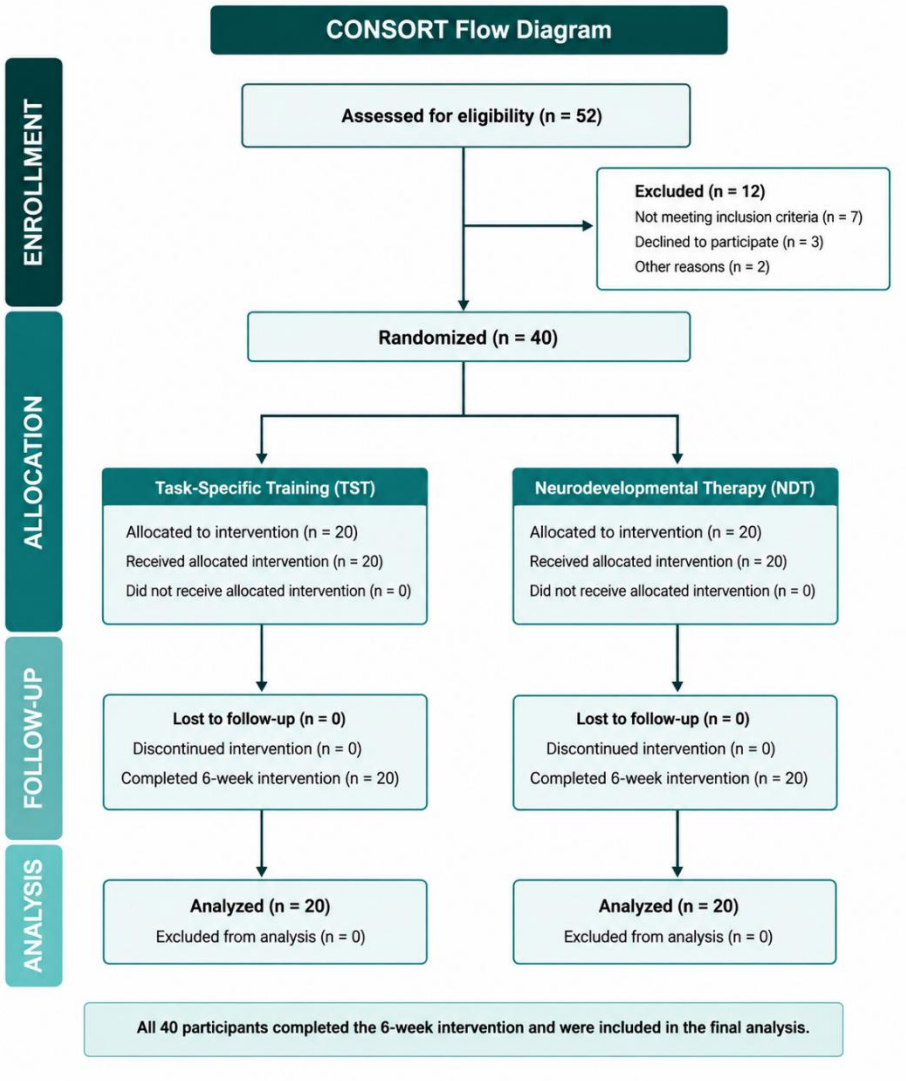

Figure 1 CONSORT Flowchart

Within-group pre-intervention and post-intervention differences in PBS, TCMS, and WeeFIM scores were evaluated using paired-samples t-tests. Between-group comparisons of the reported post-intervention outcome scores were performed using independent-samples t-tests. Statistical significance was defined as a two-sided p-value <0.05.

RESULTS

All 40 children enrolled in the trial completed the six-week intervention and were included in the analysis, with 20 participants in the Task-Specific Training group and 20 in the Neurodevelopmental Therapy group. Baseline demographic and clinical characteristics are presented in Table 1. The groups were comparable in age, sex distribution, GMFCS level, and baseline PBS, TCMS, and WeeFIM scores, with no statistically significant between-group differences at baseline.

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Characteristic	Task-Specific Training (n = 20)	Neurodevelopmental Therapy (n = 20)	Test statistic	p-value
Age, years, mean ± SD	8.20 ± 2.11	8.35 ± 1.98	t = −0.23	0.818
Sex, n (%)			χ^2 = 0.10	0.749
Male	12 (60.0)	11 (55.0)		
Female	8 (40.0)	9 (45.0)		
GMFCS level, n (%)			χ^2 = 0.14	0.934
Level I	7 (35.0)	6 (30.0)		
Level II	8 (40.0)	9 (45.0)		
Level III	5 (25.0)	5 (25.0)		
PBS baseline, mean ± SD	36.90 ± 4.52	36.70 ± 4.44	t = 0.14	0.888
TCMS baseline, mean ± SD	39.15 ± 5.11	39.40 ± 4.98	t = −0.16	0.876
WeeFIM baseline, mean ± SD	82.45 ± 6.92	82.10 ± 7.16	t = 0.16	0.876

GMFCS, Gross Motor Function Classification System; PBS, Pediatric Balance Scale; TCMS, Trunk Control Measurement Scale; WeeFIM, Functional Independence Measure for Children. Continuous variables were compared using independent-samples t-tests and categorical variables using Pearson chi-square tests.

Following six weeks of treatment, mean scores increased on all three outcome measures in both intervention groups (Table 2). In the Task-Specific Training group, the PBS score increased from 36.90 ± 4.52 to 48.20 ± 3.41, corresponding to an observed mean increase of 11.30 points. The Neurodevelopmental Therapy group increased from 36.70 ± 4.44 to 43.10 ± 3.86, an observed increase of 6.40 points. Within-group pre–post comparisons were statistically significant in both groups ($p < 0.001$).

TCMS scores increased from 39.15 ± 5.11 to 50.85 ± 4.08 in the Task-Specific Training group, representing an observed mean increase of 11.70 points, compared with an increase from 39.40 ± 4.98 to 45.25 ± 4.47 in the Neurodevelopmental Therapy group, corresponding to an observed increase of 5.85 points. Both within-group comparisons were statistically significant ($p < 0.001$).

Functional independence also increased in both groups. Mean WeeFIM scores increased from 82.45 ± 6.92 at baseline to 101.70 ± 5.81 after Task-Specific Training, an observed increase of 19.25 points. In the Neurodevelopmental Therapy group, mean WeeFIM scores increased from 82.10 ± 7.16 to 92.45 ± 6.36, corresponding to an observed increase of 10.35 points. Both within-group comparisons were statistically significant ($p < 0.001$).

Table 2. Pre- and Post-Intervention Outcome Scores Within Each Treatment Group

Outcome	Group	Baseline, mean ± SD	Post-intervention, mean ± SD	Observed mean change*	Within-group p-value†
PBS	Task-Specific Training	36.90 ± 4.52	48.20 ± 3.41	+11.30	<0.001
	Neurodevelopmental Therapy	36.70 ± 4.44	43.10 ± 3.86	+6.40	<0.001
TCMS	Task-Specific Training	39.15 ± 5.11	50.85 ± 4.08	+11.70	<0.001
	Neurodevelopmental Therapy	39.40 ± 4.98	45.25 ± 4.47	+5.85	<0.001
WeeFIM	Task-Specific Training	82.45 ± 6.92	101.70 ± 5.81	+19.25	<0.001
	Neurodevelopmental Therapy	82.10 ± 7.16	92.45 ± 6.36	+10.35	<0.001

Observed mean change was calculated as post-intervention mean minus baseline mean. Because the SDs of paired change scores were unavailable, confidence intervals and effect sizes for within-group change were not calculated. †Within-group p-values are those reported for paired-samples t-tests.

Table 3. Between-Group Comparison of Post-Intervention Outcomes

Outcome	Task-Specific Training, mean ± SD	Neurodevelopmental Therapy, mean ± SD	Mean difference (TST − NDT)	95% CI	t (df = 38)	p-value	Hedges' g
PBS	48.20 ± 3.41	43.10 ± 3.86	5.10	2.77 to 7.43	4.43	<0.001	1.37
TCMS	50.85 ± 4.08	45.25 ± 4.47	5.60	2.86 to 8.34	4.14	<0.001	1.28
WeeFIM	101.70 ± 5.81	92.45 ± 6.36	9.25	5.35 to 13.15	4.80	<0.001	1.49

Positive mean differences favor Task-Specific Training. Between-group comparisons were based on independent-samples t-tests. Hedges' g was calculated from the reported group means, standard deviations, and sample sizes; positive values indicate higher post-intervention scores in the Task-Specific Training group.

At the six-week assessment, the Task-Specific Training group had higher scores than the Neurodevelopmental Therapy group for all three outcomes (Table 3). For PBS, the post-intervention mean difference was 5.10 points (95% CI 2.77 to 7.43), with a corrected independent-samples t value of 4.43 ($p < 0.001$). The standardized between-group effect was large (Hedges' $g = 1.37$). For TCMS, the post-intervention mean difference was 5.60 points (95% CI 2.86 to 8.34; $t = 4.14$; $p < 0.001$), corresponding to a large standardized effect (Hedges' $g = 1.28$). The WeeFIM difference was 9.25 points in favor of Task-Specific Training (95% CI 5.35 to 13.15; $t = 4.80$; $p < 0.001$), with Hedges' $g = 1.49$.

Overall, both treatment groups demonstrated statistically significant within-group increases in balance, trunk control, and functional independence over six weeks. At post-intervention assessment, Task-Specific Training was associated with significantly higher PBS, TCMS, and WeeFIM scores than Neurodevelopmental Therapy, with large standardized between-group differences across all three outcomes. Because the available summary data do not provide the variance of individual change scores, these analyses establish differences in post-intervention scores but do not constitute a direct inferential test of whether the magnitude of pre–post change differed significantly between groups.

DISCUSSION

The present randomized controlled trial compared Task-Specific Training (TST) with Neurodevelopmental Therapy (NDT) for balance, postural control, and functional independence in children with spastic cerebral palsy. Both groups demonstrated statistically significant within-group improvements in PBS, TCMS, and WeeFIM scores after six weeks of treatment. At the post-intervention assessment, however, children receiving TST had higher scores than those receiving NDT for PBS (mean difference 5.10 points, 95% CI 2.77–7.43; Hedges' $g = 1.37$), TCMS (mean difference 5.60 points, 95% CI 2.86–8.34; Hedges' $g = 1.28$), and WeeFIM (mean difference 9.25 points, 95% CI 5.35–13.15; Hedges' $g = 1.49$). These large standardized differences indicate a substantial separation between the groups at six weeks, although the available aggregate data support inference regarding post-intervention scores rather than a formal between-group test of individual change.

The higher post-intervention PBS score in the TST group is consistent with evidence supporting task-oriented and task-specific approaches for functional balance in children with cerebral palsy. Systematic review evidence indicates that task-oriented training can improve balance, gross motor function, and activities of daily living, while reviews focused specifically on balance have emphasized the value of repetitive functional practice in developing postural responses during meaningful movement (3,4). Comparative clinical studies similarly report improvements in balance and functional mobility when children repeatedly practice goal-directed tasks rather than relying exclusively on impairment-focused treatment (5,12,13). A systematic review of task-oriented training also supports improvements in motor performance following repeated practice of functionally relevant activities (14). The present findings are therefore clinically plausible because activities such as sit-to-stand transfer, obstacle negotiation, stair

climbing, step-up and step-down exercises, reaching, weight shifting, and functional walking repeatedly challenge the limits of stability during tasks resembling those encountered in everyday life.

Postural control, measured using the TCMS, also demonstrated a marked between-group difference at six weeks. Trunk control is fundamental to the maintenance of proximal stability during reaching, transfers, standing, gait, and other coordinated extremity movements, and interventions directed toward the trunk have demonstrated beneficial effects on balance and gross motor performance in children with cerebral palsy (2,10). Randomized evidence involving proprioceptive neuromuscular facilitation has likewise shown that interventions requiring coordinated trunk activation can improve trunk control and functional skills (15). More intensive programs combining functional task practice with movement-pattern training have also reported improvements in postural control and gross motor performance (16). In the present intervention, repeated reaching, transfers, stepping, obstacle negotiation, and dynamic weight shifting required ongoing anticipatory and reactive adjustments of the trunk, providing a plausible functional explanation for the higher TCMS scores observed after TST.

Functional independence was another important outcome because the ultimate objective of pediatric rehabilitation extends beyond improvement of isolated impairments to greater independence in daily activities. WeeFIM scores increased in both treatment groups but were substantially higher after six weeks in the TST group. The WeeFIM has established psychometric utility for assessing functional abilities in children with cerebral palsy (11). Previous task-oriented rehabilitation research has reported improvement not only in balance and gross motor function but also in activities of daily living and functional independence (3,17). Interventions integrating sensory, perceptual, and motor practice have similarly demonstrated that structured functional training can influence activities of daily living in children with cerebral palsy (18). Because TST directly rehearses actions used in mobility and everyday activities, the skills practiced during treatment may have greater opportunity to transfer to functional performance than exercises performed primarily at an impairment level.

The pattern observed across PBS, TCMS, and WeeFIM is also compatible with contemporary principles of motor learning. Task-specific rehabilitation emphasizes repeated performance of meaningful actions, active participation, problem solving, feedback, and adaptation of movement strategies to task demands. Randomized task-specific training has demonstrated that children with cerebral palsy can acquire functional motor skills when practice is closely aligned with the target activity (7). Other active rehabilitation approaches, including dual-task exercise and game-based training, also support the use of repeated, goal-directed motor challenges to improve functional performance and balance (19,20). Comparisons between task-oriented training and other active therapeutic approaches have reported gains in mobility and balance (21), while task-oriented upper-extremity practice similarly illustrates the broader principle that repeated practice of the targeted functional activity can facilitate motor performance (22). These observations support a motor-learning interpretation of the present findings, although neuroplastic changes were not directly measured in this trial and should therefore be considered a plausible mechanism rather than a demonstrated biological outcome.

The significant within-group improvements observed after NDT are also clinically relevant and should not be overlooked. NDT emphasizes postural alignment, facilitated movement, weight transfer, trunk control, and management of atypical movement patterns. Evidence regarding its comparative effectiveness remains mixed: meta-analytic findings have not established consistent superiority of NDT over active alternative interventions, whereas individual studies continue to report improvements in gross motor function and activities of daily living following NDT-based treatment (1,6). Contemporary trials of active balance interventions, including gamified and virtual-reality approaches, further demonstrate that children with cerebral palsy can improve balance and postural control through several rehabilitation modalities rather than through a single therapeutic model (23,24). The present findings therefore do not indicate that NDT is ineffective; rather, they show that under the treatment conditions evaluated, the TST group achieved higher post-intervention scores across all three assessed domains.

The broader rehabilitation literature increasingly supports active, repetitive, and functionally oriented exercise for children with cerebral palsy. Programs combining balance exercises with locomotor training have demonstrated improvements in mobility and balance (25), while task-oriented training has also produced favorable functional mobility outcomes when compared with alternative circuit-based approaches (26). Recent systematic reviews examining exercise-based and mobility-oriented interventions emphasize the potential value of active rehabilitation while also identifying heterogeneity in treatment protocols, treatment dose, outcome selection, and methodological quality (27,28). Additional task-oriented exercise research has reported improvements in gross motor function in children with spastic cerebral palsy (29). Taken together, these findings support the clinical relevance of task-based practice but also indicate that the optimal dose, progression, combination of activities, and long-term sustainability of treatment effects remain incompletely established. The observed differences have practical implications for pediatric physiotherapy. TST can be structured around common functional activities and adapted according to a child's mobility level without necessarily requiring specialized equipment. Incorporating repeated sit-to-stand practice, reaching, stepping, weight shifting, obstacle negotiation, stair-related activities, and walking tasks into rehabilitation may provide a pragmatic method of directly targeting balance, trunk control, and functional independence. Nevertheless, the present results should support integration rather than universal replacement of other therapeutic approaches. Treatment selection should remain individualized according to motor severity, functional goals, associated impairments, participation priorities, and the child's capacity to engage safely in task practice. Current evidence favors active functional rehabilitation while showing that several exercise-based strategies can contribute to motor improvement (1,3,17,27,28).

Several methodological strengths support interpretation of the findings. The study used a randomized parallel-group design, equal group sizes, identical treatment frequency and duration, standardized assessment time points, and established clinical measures of balance, trunk control, and functional independence. All 40 participants completed the six-week intervention, eliminating attrition between enrollment and post-treatment assessment. The inclusion of PBS, TCMS, and WeeFIM also allowed treatment response to be evaluated across three complementary domains rather than through a single motor outcome.

The findings should nevertheless be interpreted in light of important limitations. The sample comprised only 40 children and recruitment was confined to a single rehabilitation center, limiting external generalizability. Treatment lasted six weeks and no follow-up assessment was conducted, preventing conclusions regarding persistence of the observed differences after treatment cessation. Gait characteristics, muscle strength, participation, and quality of life were not assessed, and therefore the findings cannot be generalized to these outcomes. The available aggregate results permit accurate comparison of post-intervention group means but do not provide the variance of individual change scores required for a direct inferential comparison of pre–post change. A baseline-adjusted analysis such as ANCOVA would provide a stronger estimate of the comparative intervention effect. In addition, details required for a complete assessment of risk of bias—including the random-sequence generation method and allocation concealment—were not available in the study information used for the present analysis. Future trials should therefore include larger multicenter samples, clearly reported randomization and allocation procedures, prospectively justified sample sizes, standardized intervention progression and fidelity measures, and longer follow-up periods. Inclusion of objective gait analysis, muscle-strength assessment, participation measures, and quality-of-life outcomes would provide a more comprehensive assessment of rehabilitation effects. Analysis using baseline-adjusted treatment estimates with confidence intervals would also improve precision and clinical interpretability. Within these limitations, the present findings support further evaluation of TST as an active functional rehabilitation strategy for children with spastic cerebral palsy.

CONCLUSION

Both Task-Specific Training and Neurodevelopmental Therapy were associated with significant within-group improvements in balance, postural control, and functional independence after six weeks in children with spastic cerebral palsy. At the post-intervention assessment, the Task-Specific Training group had significantly higher PBS, TCMS, and WeeFIM scores than the Neurodevelopmental Therapy group, with large standardized between-group differences across all three outcomes. These findings support Task-Specific Training as a promising function-oriented rehabilitation approach for improving balance, trunk control, and independence in this population. Larger, rigorously reported trials with baseline-adjusted analyses and longer follow-up are required to determine the durability and generalizability of these comparative effects.

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