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Original Article

The Effects of Connective Tissue Manipulation versus Proprioceptive Neuromuscular Facilitation on Gait, Postural Control, and Hip Alignment in Children with Cerebral Palsy and Hip Displacement

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ABSTRACT

Background: Cerebral palsy is commonly associated with impaired gait, reduced postural control, abnormal pelvic mechanics, and secondary hip displacement, all of which may limit functional mobility in children. Rehabilitation strategies that address neuromotor control and soft-tissue restrictions may improve walking performance and balance; however, comparative evidence between connective tissue manipulation and proprioceptive neuromuscular facilitation remains limited. Objective: To compare the effects of connective tissue manipulation and proprioceptive neuromuscular facilitation on gait parameters, postural control, and hip alignment in children with spastic cerebral palsy and hip displacement. Methods: A quasi-experimental comparative study was conducted among 30 children aged 6–14 years with spastic cerebral palsy, GMFCS levels I–III, and imaging-confirmed hip displacement. Participants were allocated into a connective tissue manipulation group and a proprioceptive neuromuscular facilitation group, with 15 participants in each group. Both groups received 45-minute sessions three times weekly for 8 weeks. Gait speed, stride length, gait symmetry, Pediatric Balance Scale score, and Reimers Migration Percentage were assessed before and after intervention. Results: The proprioceptive neuromuscular facilitation group showed greater improvements in gait speed (+0.15 m/s), stride length (+7.4 cm), symmetry index (+0.08), and Pediatric Balance Scale score (+6.7) than the connective tissue manipulation group, which improved by +0.06 m/s, +1.6 cm, +0.02, and +1.9, respectively. Reimers Migration Percentage decreased modestly in both groups, with greater numerical reduction after proprioceptive neuromuscular facilitation (-2.5%) than connective tissue manipulation (-1.3%). Conclusion: Proprioceptive neuromuscular facilitation produced larger short-term improvements in gait and postural control than connective tissue manipulation, while hip alignment changes remained limited over 8 weeks. Keywords: Cerebral Palsy; Connective Tissue Manipulation; Proprioceptive Neuromuscular Facilitation; Gait; Postural Control; Hip Displacement; Pediatric Rehabilitation.

INTRODUCTION

Cerebral palsy is a non-progressive neurodevelopmental disorder characterized by disturbances in movement, posture, muscle tone, selective motor control, and functional mobility, with gait impairment representing one of the most clinically important limitations among ambulatory children. Children with spastic cerebral palsy frequently demonstrate reduced gait speed, shortened stride length, asymmetrical lower-limb loading, impaired trunk control, and deficient anticipatory and reactive postural adjustments, all of which restrict independence and increase the risk of falls during daily activities (1). These motor impairments are often compounded by secondary musculoskeletal complications, particularly hip displacement, pelvic asymmetry, soft-tissue shortening, and altered lower-limb biomechanics, which may further compromise walking efficiency, postural stability, comfort, and long-term participation in age-appropriate activities (2).

Hip displacement in children with cerebral palsy is a progressive musculoskeletal concern associated with abnormal muscle forces, impaired weight-bearing symmetry, reduced motor control, and altered pelvic mechanics. Although orthopedic surveillance and medical management are central to preventing severe displacement and dislocation, rehabilitation interventions remain important for optimizing movement quality, maintaining soft-tissue extensibility, improving postural control, and enhancing functional mobility. Postural control is especially relevant because efficient gait requires continuous integration of sensory input, trunk stability, pelvic alignment, and coordinated lower-limb activation. In children with spastic cerebral palsy, impaired proprioceptive processing, abnormal co-contraction, muscle weakness, and compensatory movement strategies may reduce the ability to maintain dynamic balance during walking and transitional activities (3,4).

Proprioceptive neuromuscular facilitation is a rehabilitation approach that uses diagonal and spiral movement patterns, manual resistance, tactile cues, stretch, and proprioceptive input to facilitate coordinated muscle activation and improve neuromotor control. In pediatric cerebral palsy rehabilitation, PNF-based interventions have been used to target trunk control, pelvic mobility, lower-limb coordination, balance, and gait-related performance. Emerging evidence suggests that PNF may improve functional skills, muscle strength, and trunk control in children with cerebral palsy, supporting its clinical relevance for gait and postural rehabilitation (5). Pelvic and lower-limb PNF techniques may be particularly useful in ambulatory children because they directly address movement components required for step initiation, stance stability, limb advancement, and symmetrical gait performance (6).

Connective tissue manipulation is a manual therapy technique directed toward fascial mobility, soft-tissue pliability, local circulation, and joint-related mechanical restrictions. In children with cerebral palsy, soft-tissue stiffness, adaptive shortening, fascial restriction, and altered pelvic or hip mechanics may contribute to reduced range of motion and inefficient movement patterns. Manual soft-tissue approaches may therefore provide a plausible adjunctive strategy for improving tissue extensibility and preparing the child for functional training. However, the evidence supporting connective tissue manipulation for gait, postural control, and hip alignment in children with cerebral palsy remains limited, and available literature on manual or myofascial approaches often focuses on different populations, non-motor outcomes, or adjunctive interventions rather than direct functional mobility outcomes (7,8).

Despite growing interest in both neuromotor facilitation and soft-tissue-based interventions, there remains a clear knowledge gap regarding their comparative effects in children with spastic cerebral palsy who also present with hip displacement. Existing studies more commonly examine balance, trunk control, stretching, orthotic management, or general rehabilitation strategies, while fewer investigations directly compare a proprioceptive neuromuscular intervention with a connective tissue-based manual intervention using clinically meaningful gait, balance, and radiographic hip-alignment outcomes. This gap is important because children with cerebral palsy and hip displacement require interventions that not only improve short-term functional mobility but also address biomechanical and postural factors that may influence long-term hip health and walking ability (9,10).

Using a PICO framework, the population of interest in the present study was ambulatory children with spastic cerebral palsy and hip displacement; the intervention was connective tissue manipulation; the comparator was proprioceptive neuromuscular facilitation; and the outcomes were gait parameters, postural control, and hip alignment. Accordingly, this study aimed to compare the effects of connective tissue manipulation and proprioceptive neuromuscular facilitation on gait speed, stride length, gait symmetry, Pediatric Balance Scale performance, and Reimers Migration Percentage in children with spastic cerebral palsy and hip displacement. It was hypothesized that proprioceptive neuromuscular facilitation would produce greater improvements in gait and postural control than connective tissue manipulation, while changes in radiographic hip alignment would be limited over the short intervention period.

MATERIALS AND METHODS

A quasi-experimental comparative pretest–posttest study was conducted to evaluate the effects of connective tissue manipulation and proprioceptive neuromuscular facilitation on gait parameters, postural control, and hip alignment in children with spastic cerebral palsy and hip displacement. The study followed a two-arm parallel intervention design, with eligible participants allocated into two treatment groups: a connective tissue manipulation group and a proprioceptive neuromuscular facilitation group. Outcomes were assessed at baseline before initiation of treatment and after completion of the 8-week intervention period to determine within-group and between-group changes in functional and radiographic measures.

Children aged 6 to 14 years with a confirmed diagnosis of spastic cerebral palsy, Gross Motor Function Classification System levels I to III, and clinical evidence of hip displacement confirmed through imaging were included. Eligible participants were ambulatory with or without an assistive device and were able to participate in active therapeutic sessions. Children were excluded if they had undergone orthopedic surgery within the previous 12 months, had received botulinum toxin injections within the previous 6 months, or had severe cognitive impairment that prevented comprehension of instructions or active cooperation during therapy and assessment procedures. Written informed consent was obtained from parents or legal guardians before enrollment.

A total of 30 participants meeting the eligibility criteria were enrolled and allocated into two equal groups, with 15 children in the connective tissue manipulation group and 15 children in the proprioceptive neuromuscular facilitation group. Baseline demographic and clinical characteristics, including age and GMFCS level, were recorded before intervention. Standardized baseline assessment was performed before treatment initiation, and the same outcome measures were repeated after 8 weeks. To reduce measurement bias, assessment procedures, outcome definitions, and timing of evaluation were kept consistent across both groups.

Participants in the connective tissue manipulation group received a structured manual therapy protocol focused on the hip girdle and pelvic soft-tissue structures. Treatment targeted the gluteal fascia, tensor fasciae latae, iliotibial band, peri-hip connective tissues, and pelvic myofascial chains with the aim of improving soft-tissue pliability, reducing fascial restriction, and facilitating more efficient pelvic and hip movement during functional activity. Each session lasted 45 minutes and was delivered three times per week for 8 consecutive weeks.

Participants in the proprioceptive neuromuscular facilitation group received lower-limb and pelvic PNF-based therapeutic exercises designed to improve proprioceptive input, neuromuscular control, postural stability, and gait-related movement coordination. The intervention emphasized pelvic and lower-limb movement patterns relevant to walking, including facilitation of controlled weight shift, pelvic mobility, stance stability, limb advancement, and coordinated activation of muscles involved in gait and balance. Sessions were matched to the connective tissue manipulation group in duration and frequency, with 45-minute sessions delivered three times per week for 8 weeks.

Both groups also received standardized task-oriented walking practice during the intervention period to support functional transfer of treatment effects into gait performance. Walking practice emphasized repeated functional stepping, controlled weight transfer, stance-phase stability, and symmetrical lower-limb loading. The frequency and duration of this component were kept consistent between groups to minimize performance bias related to unequal exposure to functional gait training.

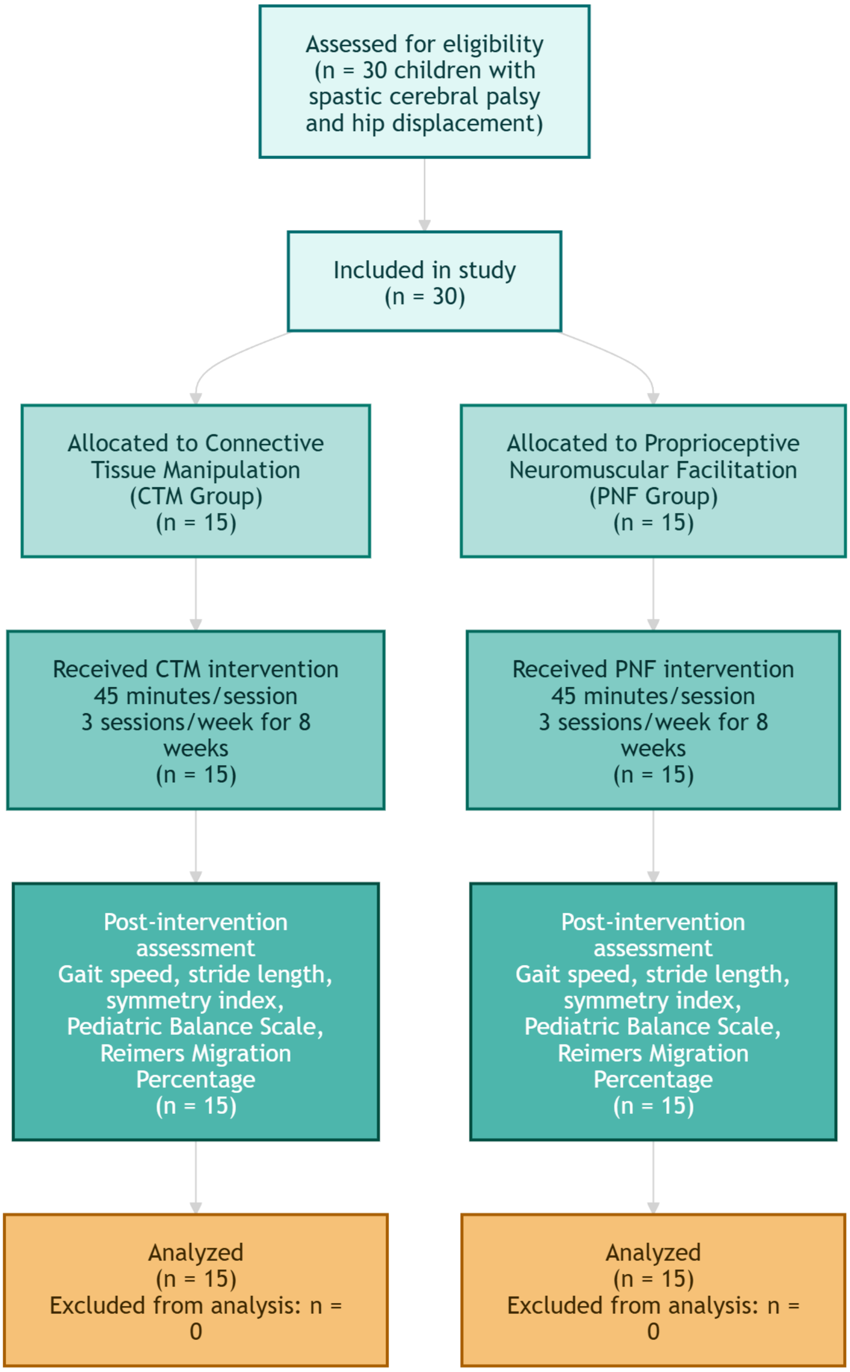

Figure 1. CONSORT-Style Participant Flow Diagram for the Quasi-Experimental Comparison of CTM and PNF

The primary functional outcomes included gait speed, stride length, and gait symmetry. Gait speed was recorded in meters per second, stride length in centimeters, and gait symmetry using a symmetry index, with higher symmetry values indicating more balanced gait performance. Gait parameters were assessed through three-dimensional motion analysis. Postural control was assessed using the Pediatric Balance Scale, with scores ranging from 0 to 56 and higher scores indicating better functional balance. Hip alignment was assessed radiographically using Reimers Migration Percentage, with lower values indicating reduced lateral migration of the femoral head. Pelvic alignment was assessed through pelvic obliquity measures where applicable.

Data were recorded at two time points: baseline and immediately after the 8-week intervention. The independent variable was intervention group, categorized as connective tissue manipulation or proprioceptive neuromuscular facilitation. Dependent variables were gait speed, stride length, symmetry index, Pediatric Balance Scale score, and Reimers Migration Percentage. Age, GMFCS level, baseline functional status, and baseline hip displacement severity were considered clinically relevant participant characteristics for interpretation of treatment response.

Data were entered into a structured database and checked for completeness, coding accuracy, and range errors before analysis. Continuous variables were summarized as mean and standard deviation, while categorical variables were summarized as frequencies and percentages. Baseline comparability between groups was assessed using appropriate descriptive and inferential statistics according to variable type. Within-group pre–post changes were evaluated for each outcome, and between-group differences in change over time were analyzed to compare the relative effects of the two interventions.

Repeated-measures analysis of variance was used to examine the effects of time, group, and group-by-time interaction for continuous outcomes measured before and after intervention. The group-by-time interaction was treated as the main comparative effect for determining whether change differed between the connective tissue manipulation and proprioceptive neuromuscular facilitation groups. Statistical significance was set at $p<0.05$. Results were reported using mean values, standard deviations, mean changes, and p-values, with interpretation based on both statistical significance and clinical relevance of observed changes.

Ethical approval was obtained from the institutional review board before commencement of the study. Participation was voluntary, and informed consent was obtained from parents or legal guardians of all enrolled children. Participant confidentiality was maintained throughout data collection, analysis, and reporting. Assessment forms and clinical data were coded to protect participant identity, and all procedures were conducted according to ethical principles for research involving pediatric participants.

RESULTS

A total of 30 children with spastic cerebral palsy and hip displacement were included in the analysis, with 15 participants allocated to the connective tissue manipulation group and 15 participants allocated to the proprioceptive neuromuscular facilitation group. The mean age was 9.8 ± 2.4 years in the connective tissue manipulation group and 10.2 ± 2.1 years in the proprioceptive neuromuscular facilitation group. Gross Motor Function Classification System levels were similarly distributed between groups, with level II being the most frequent classification in both groups.

Figure Description: The CONSORT-style flow diagram summarizes participant progression through the quasi-experimental comparative study. A total of 30 children with spastic cerebral palsy and hip displacement were assessed for eligibility and included in the study. Participants were allocated equally into two intervention groups, with 15 children receiving connective tissue manipulation and 15 children receiving proprioceptive neuromuscular facilitation. Both groups completed 45-minute treatment sessions three times per week for 8 weeks. Post-intervention assessments were conducted for all participants using gait speed, stride length, symmetry index, Pediatric Balance Scale, and Reimers Migration Percentage as outcome measures. All enrolled participants completed the intervention and were included in the final analysis, with no exclusions or losses to follow-up reported.

The two groups were comparable at baseline in age and GMFCS distribution. The PNF group was slightly older by 0.4 years on average compared with the CTM group, while the distribution of functional severity was closely balanced. GMFCS level II accounted for the largest proportion of participants in both groups, representing 46.7% of the CTM group and 40.0% of the PNF group. GMFCS level III was identical between groups, with 5 participants in each group.

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	CTM Group (n=15)	PNF Group (n=15)	p-value
Age, years, mean ± SD	9.8 ± 2.4	10.2 ± 2.1	>0.05
GMFCS Level I, n	3	4	>0.05
GMFCS Level II, n	7	6	>0.05
GMFCS Level III, n	5	5	>0.05

Gait outcomes improved in both groups after 8 weeks of intervention, although the magnitude of improvement was greater in the proprioceptive neuromuscular facilitation group. In the connective tissue manipulation group, gait speed increased from 0.72 ± 0.18 m/s to 0.78 ± 0.17 m/s, representing a mean increase of 0.06 m/s. In the proprioceptive neuromuscular facilitation group, gait speed increased from 0.70 ± 0.16 m/s to 0.85 ± 0.15 m/s, representing a mean increase of 0.15 m/s. Stride length increased by 1.6 cm in the CTM group and by 7.4 cm in the PNF group. The symmetry index improved from 0.85 ± 0.10 to 0.87 ± 0.08 in the CTM group and from 0.84 ± 0.11 to 0.92 ± 0.07 in the PNF group.

Table 2. Pre- and Post-Intervention Gait Outcomes

Gait Parameter	CTM Pre, Mean ± SD	CTM Post, Mean ± SD	CTM Mean Change	CTM p-value	PNF Pre, Mean ± SD	PNF Post, Mean ± SD	PNF Mean Change	PNF p-value
Gait Speed (m/s)	0.72 ± 0.18	0.78 ± 0.17	+0.06	>0.05	0.70 ± 0.16	0.85 ± 0.15	+0.15	<0.05
Stride Length (cm)	78.5 ± 9.4	80.1 ± 8.9	+1.6	>0.05	77.9 ± 10.1	85.3 ± 9.2	+7.4	<0.05
Symmetry Index	0.85 ± 0.10	0.87 ± 0.08	+0.02	>0.05	0.84 ± 0.11	0.92 ± 0.07	+0.08	<0.05

The largest gait-related improvement was observed in the PNF group. Gait speed improved by 21.4% in the PNF group compared with 8.3% in the CTM group. Stride length increased by 9.5% after PNF compared with 2.0% after CTM. Gait symmetry improved by 9.5% in the PNF group compared with 2.4% in the CTM group. These findings indicate that the PNF group demonstrated greater functional gains across all measured gait parameters, with statistically significant within-group improvement for gait speed, stride length, and symmetry index.

Postural control improved in both groups, with a larger increase in Pediatric Balance Scale scores in the proprioceptive neuromuscular facilitation group. The CTM group improved from 34.3 ± 5.8 to 36.2 ± 6.1, corresponding to a mean increase of 1.9 points. The PNF group improved from 33.8 ± 5.9 to 40.5 ± 6.0, corresponding to a mean increase of 6.7 points.

Table 3. Pre- and Post-Intervention Postural Control Outcome

Outcome	CTM Pre, Mean ± SD	CTM Post, Mean ± SD	CTM Mean Change	CTM p-value	PNF Pre, Mean ± SD	PNF Post, Mean ± SD	PNF Mean Change	PNF p-value
Pediatric Balance Scale Score	34.3 ± 5.8	36.2 ± 6.1	+1.9	>0.05	33.8 ± 5.9	40.5 ± 6.0	+6.7	<0.05

The improvement in postural control was more pronounced following PNF. The Pediatric Balance Scale score increased by 19.8% in the PNF group compared with 5.5% in the CTM group. The absolute between-group difference in mean improvement was 4.8 points in favor of PNF, indicating a stronger functional balance response after proprioceptive neuromuscular facilitation.

Hip alignment showed small numerical improvements in both groups after intervention. Reimers Migration Percentage decreased from 38.2 ± 12.1% to 36.9 ± 11.8% in the CTM group, corresponding to a mean reduction of 1.3 percentage points. In the PNF group, Reimers Migration Percentage decreased from 37.5 ± 11.9% to 35.0 ± 12.0%, corresponding to a mean reduction of 2.5 percentage points.

Although both groups demonstrated small reductions in Reimers Migration Percentage, the changes were not statistically significant. The relative reduction was 3.4% in the CTM group and 6.7% in the PNF group. The greater numerical reduction in the PNF group suggests a modest favorable trend, but the absence of statistical significance indicates that neither intervention produced a clear short-term radiographic change in hip alignment over the 8-week treatment period.

Table 4. Pre- and Post-Intervention Hip Alignment Outcome

Outcome	CTM Pre, Mean ± SD	CTM Post, Mean ± SD	CTM Mean Change	CTM p-value	PNF Pre, Mean ± SD	PNF Post, Mean ± SD	PNF Mean Change	PNF p-value
Reimers Migration Percentage (%)	38.2 ± 12.1	36.9 ± 11.8	-1.3	>0.05	37.5 ± 11.9	35.0 ± 12.0	-2.5	>0.05

A comparative summary of percentage change across all outcomes showed that PNF produced consistently larger improvements than CTM for gait and postural control outcomes. The greatest relative improvement after PNF was observed in gait speed, followed by Pediatric Balance Scale score, stride length, and gait symmetry. In contrast, CTM produced smaller improvements across all functional outcomes. Hip alignment showed the smallest magnitude of change in both groups.

Table 5. Comparative Percentage Change Across Outcomes

Outcome	CTM Percentage Change	PNF Percentage Change
Gait Speed	+8.3%	+21.4%
Stride Length	+2.0%	+9.5%
Symmetry Index	+2.4%	+9.5%
Pediatric Balance Scale	+5.5%	+19.8%
Reimers Migration Percentage	-3.4%	-6.7%

Overall, the proprioceptive neuromuscular facilitation group demonstrated greater improvement across all functional outcomes compared with the connective tissue manipulation group. The most clinically notable differences were observed in gait speed, which increased by 0.15 m/s after PNF compared with 0.06 m/s after CTM, and Pediatric Balance Scale score, which increased by 6.7 points after PNF compared with 1.9 points after CTM. Hip alignment improved numerically in both groups, but the magnitude of change was small and not statistically significant.

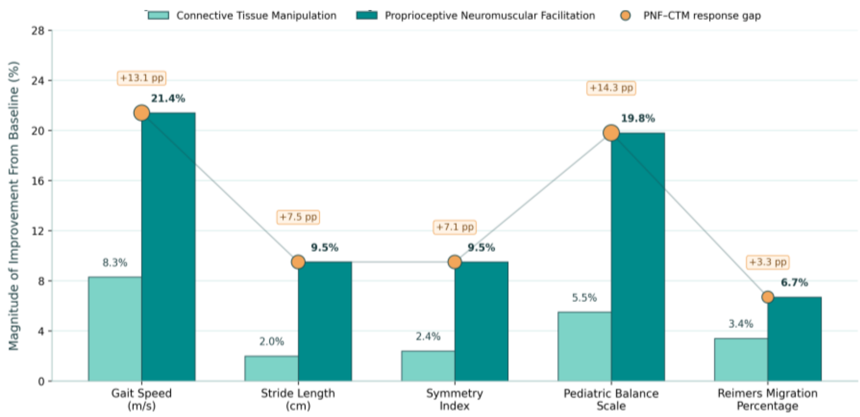

Figure 2. Comparative Functional Improvement After Connective Tissue Manipulation and Proprioceptive Neuromuscular Facilitation in Children With Cerebral Palsy and Hip Displacement

Figure description: The comparative response gradient demonstrates consistently greater improvement after proprioceptive neuromuscular facilitation than connective tissue manipulation across all measured outcomes. The largest advantage was observed for Pediatric Balance Scale score, where PNF produced a 19.8% improvement compared with 5.5% after CTM, yielding a 14.3 percentage-point response gap. Gait speed also showed a marked functional advantage for PNF, improving by 21.4% compared with 8.3% after CTM, corresponding to a 13.1 percentage-point difference. Stride length and symmetry index both improved by 9.5% after PNF, compared with 2.0% and 2.4% after CTM, respectively. Reimers Migration Percentage showed the smallest response magnitude in both groups, with a 6.7% reduction after PNF and 3.4% reduction after CTM, indicating limited short-term radiographic change despite stronger functional gains in the PNF group.

DISCUSSION

The present study demonstrated that both connective tissue manipulation and proprioceptive neuromuscular facilitation produced favorable short-term changes in gait performance, postural control, and hip alignment indicators among ambulatory children with spastic cerebral palsy and hip displacement; however, the magnitude of improvement was consistently greater in the proprioceptive neuromuscular facilitation group. After 8 weeks of intervention, gait speed increased by 0.15 m/s in the proprioceptive neuromuscular facilitation group compared with 0.06 m/s in the connective tissue manipulation group, while stride length improved by 7.4 cm compared with 1.6 cm, respectively. Similarly, gait symmetry improved by 0.08 after proprioceptive neuromuscular facilitation compared with 0.02 after connective tissue manipulation, indicating that neuromuscular facilitation produced broader functional gains across multiple gait domains. These findings support the clinical relevance of interventions that directly target proprioceptive input, pelvic control, coordinated lower-limb activation, and task-specific movement patterns in children with cerebral palsy (11,12).

The greater improvement in gait outcomes after proprioceptive neuromuscular facilitation may be explained by its emphasis on diagonal and spiral movement patterns, manual resistance, proprioceptive stimulation, and facilitation of coordinated muscle recruitment. Children with spastic cerebral palsy commonly demonstrate impaired selective motor control, abnormal co-contraction, reduced postural adaptation, and inefficient lower-limb sequencing during walking. By integrating sensory cues with active movement, proprioceptive neuromuscular facilitation may enhance motor planning, improve timing of muscle activation, and support more efficient pelvic and lower-limb mechanics during gait. The observed increase in gait speed from 0.70 ± 0.16 m/s to 0.85 ± 0.15 m/s suggests a clinically meaningful improvement in walking performance, while the improvement in stride length from 77.9 ± 10.1 cm to 85.3 ± 9.2 cm indicates enhanced step progression and lower-limb advancement. These changes are consistent with previous evidence indicating that proprioceptive neuromuscular facilitation can improve functional skills, muscle strength, trunk control, balance, and gait-related performance in children with cerebral palsy (13,14).

Postural control showed a similar pattern of response. The Pediatric Balance Scale score increased by 6.7 points in the proprioceptive neuromuscular facilitation group compared with 1.9 points in the connective tissue manipulation group, representing a 19.8% improvement after proprioceptive neuromuscular facilitation and a 5.5% improvement after connective tissue manipulation. This finding is important because postural control is a central determinant of functional gait in children with cerebral palsy. Effective walking requires anticipatory and reactive balance adjustments, trunk stability, pelvic control, symmetrical loading, and the ability to maintain alignment during dynamic transitions. The larger balance response observed after proprioceptive neuromuscular facilitation suggests that facilitation of trunk–pelvis–lower limb coordination may have contributed to improved functional stability during movement. This interpretation aligns with the role of postural management and neuromotor rehabilitation in reducing movement inefficiency and supporting functional mobility in children with spastic cerebral palsy (15).

In contrast, connective tissue manipulation produced smaller but directionally positive changes in gait and balance outcomes. Gait speed increased by 8.3%, stride length by 2.0%, symmetry index by 2.4%, and Pediatric Balance Scale score by 5.5% after connective tissue manipulation. These improvements may reflect enhanced soft-tissue pliability, reduced fascial restriction, improved local tissue mobility, and greater tolerance for functional movement practice. However, the smaller magnitude of change suggests that soft-tissue-based intervention alone may be insufficient to produce substantial short-term improvements in complex motor functions such as walking speed, gait symmetry, and dynamic balance. In children with cerebral palsy, gait dysfunction is not solely mechanical; it is strongly influenced by abnormal neuromotor control, spasticity, weakness, impaired proprioception, and altered postural strategies. Therefore, while connective tissue manipulation may support tissue mobility and prepare the child for movement, interventions that actively train coordinated motor control may have greater functional transfer to gait and balance outcomes (16,17).

Hip alignment outcomes showed only modest numerical improvement in both groups. Reimers Migration Percentage decreased from 38.2 ± 12.1% to 36.9 ± 11.8% in the connective tissue manipulation group and from 37.5 ± 11.9% to 35.0 ± 12.0% in the proprioceptive neuromuscular facilitation group. Although the relative reduction was greater after proprioceptive neuromuscular facilitation, at 6.7% compared with 3.4% after connective tissue manipulation, the overall magnitude of radiographic change remained small. This finding is clinically plausible because hip displacement in cerebral palsy is influenced by long-term interactions among muscle imbalance, spasticity, growth, skeletal remodeling, pelvic mechanics, and weight-bearing patterns. An 8-week intervention may be sufficient to improve neuromotor performance and balance but may not be long enough to produce substantial structural or radiographic change in hip alignment. Rehabilitation may therefore be more effective for improving functional performance over short periods, while meaningful change in hip migration may require longer follow-up, integrated orthopedic surveillance, positioning strategies, strengthening, spasticity management, and individualized postural care (18,19).

The pattern of findings suggests that proprioceptive neuromuscular facilitation may provide a stronger functional stimulus than connective tissue manipulation for ambulatory children with cerebral palsy and hip displacement. The comparative response gradient was most pronounced for Pediatric Balance Scale score and gait speed, where proprioceptive neuromuscular facilitation exceeded connective tissue manipulation by 14.3 and 13.1 percentage points, respectively. These outcomes are clinically important because balance and walking speed directly influence independence, mobility safety, participation, and caregiver burden. The smaller between-group differences for stride length, symmetry index, and Reimers Migration Percentage indicate that some domains may respond more gradually or require combined approaches. A multimodal rehabilitation model that integrates neuromuscular facilitation, task-specific gait practice, strengthening, postural management, and selective soft-tissue techniques may therefore be more appropriate than relying on a single therapeutic approach.

The findings also highlight the distinction between functional and structural outcomes in pediatric cerebral palsy rehabilitation. Functional outcomes such as gait speed, stride length, symmetry, and balance are responsive to short-term neuromotor training because they depend on coordination, strength, sensory input, motor learning, and repeated practice. In contrast, hip displacement reflects a more slowly evolving musculoskeletal process. The limited short-term change in Reimers Migration Percentage should not be interpreted as absence of clinical value; rather, it suggests that radiographic hip alignment may require longer intervention periods and longitudinal surveillance to determine whether functional improvements can contribute to slower progression of hip migration. This distinction is important when selecting outcome measures and interpreting treatment effects in children with cerebral palsy and hip displacement.

Several limitations should be considered when interpreting these findings. The sample size was small, with 15 participants in each group, which limits statistical power and generalizability. The short intervention duration restricted evaluation of long-term functional retention and radiographic hip alignment change. The study included ambulatory children classified as GMFCS levels I to III; therefore, findings may not extend to non-ambulatory children or those with more severe motor impairment. The use of task-oriented walking practice in both groups was clinically appropriate, but it may have contributed to functional gains in both interventions. In addition, outcomes were assessed only at baseline and immediately after treatment, so maintenance of improvement beyond the intervention period remains unknown.

Despite these limitations, the study contributes clinically relevant evidence by directly comparing a soft-tissue-based manual intervention with a neuromotor facilitation approach in children with cerebral palsy and hip displacement. The results suggest that proprioceptive neuromuscular facilitation is associated with larger short-term improvements in gait speed, stride length, gait symmetry, and postural control, whereas connective tissue manipulation produces smaller functional gains and limited radiographic change. These findings support prioritizing active neuromuscular and task-specific rehabilitation strategies when the primary treatment goal is improvement in walking and balance, while connective tissue manipulation may serve as an adjunctive strategy for addressing soft-tissue restriction and movement preparation (20). Future clinical protocols may benefit from combining the tissue-mobility advantages of connective tissue manipulation with the motor-control and functional-training benefits of proprioceptive neuromuscular facilitation to address both biomechanical and neuromotor contributors to disability in children with cerebral palsy and hip displacement.

CONCLUSION

In this comparative study, proprioceptive neuromuscular facilitation produced greater short-term improvements than connective tissue manipulation in gait performance and postural control among ambulatory children with spastic cerebral palsy and hip displacement. After 8 weeks of intervention, the PNF group demonstrated larger gains in gait speed, stride length, gait symmetry, and Pediatric Balance Scale scores, indicating better functional mobility, dynamic balance, and neuromotor control. Connective tissue manipulation showed modest positive changes, suggesting potential supportive value for improving soft-tissue mobility and movement readiness, but its functional effects were smaller than those observed with PNF. Changes in Reimers Migration Percentage were limited in both groups, indicating that short-term rehabilitation may improve functional outcomes more readily than radiographic hip alignment. Overall, PNF appears to be a more effective intervention for enhancing gait and postural control in this population, while CTM may be considered as an adjunctive approach within a broader rehabilitation program targeting both neuromotor and musculoskeletal impairments.

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