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Effectiveness Of Neurodevelopmental Therapy On Trunk Control And Sitting Balance In Children With Spastic Quadriplegic Cerebral Palsy: A Quasi-Experimental Study

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ABSTRACT

Background: *Spastic quadriplegic cerebral palsy (CP) severely limits trunk control and sitting balance. Neurodevelopmental therapy (NDT) is widely used, yet its added value over conventional physiotherapy remains debated.*

Methods: *Thirty children (6–10 years; GMFCS III–IV) with spastic quadriplegic CP were allocated to NDT + conventional therapy (n = 15) or conventional therapy alone (n = 15) for 6 weeks, three 45-min sessions per week. Gross Motor Function Measure-88 (GMFM-88) and Trunk Control Measurement Scale (TCMS) were recorded pre- and post-intervention. Paired and unpaired t-tests compared within- and between-group change.*

Results: *Both groups improved significantly. In the NDT arm GMFM rose from 30.22 ± 5.79 to 35.19 ± 5.81 ($p < 0.001$) and TCMS from 11.07 ± 1.90 to 15.34 ± 2.60 ($p < 0.001$). Conventional therapy produced smaller gains (GMFM 30.05 ± 4.97 → 31.47 ± 5.21, $p = 0.0003$; TCMS 11.18 ± 3.05 → 12.71 ± 2.97, $p < 0.001$). Between-group comparison showed a clinically relevant but non-significant difference for* GMFM *($p = 0.075$) and a significant advantage for NDT on TCMS ($p = 0.015$).*

Conclusion: *Adding NDT to conventional exercises yields greater improvements in trunk control and sitting balance than conventional therapy alone in children with spastic quadriplegic CP.*

Keywords: *cerebral palsy; neurodevelopmental therapy; trunk control; sitting balance; GMFM; TCMS*

INTRODUCTION

Cerebral palsy (CP) is the leading cause of chronic motor disability in childhood, affecting an estimated 17 million people worldwide and 1–4 per 1 000 live births, with the burden concentrated in low- and middle-income regions where prenatal and intrapartum care remain uneven [1]. Spastic phenotypes account for roughly 80 % of cases; spastic quadriplegia marks the most severe end of the spectrum, compromising all four limbs and the trunk as a result of bilateral corticospinal and corticobulbar injury [2]. The consequent weakness, velocity-dependent hypertonia, and poor selective control hinder a child's ability to stabilise the trunk, shift weight, or keep the centre of mass within a very narrow base of support. These early postural deficits cascade into delayed or absent sitting, impaired reaching, and restricted exploration, shrinking opportunities for environmental learning and participation [3]. Trunk control normally matures in the first year of life and underpins virtually every gross-motor milestone as well as fine-motor tasks such as self-feeding and handwriting. Electromyographic studies show that children with CP activate deep trunk muscles later and less synchronously than their typically developing peers, correlating with slower attainment of motor milestones and reduced participation in daily routines [4]. Accordingly, contemporary rehabilitation places strong emphasis on interventions that modulate tone, elicit anticipatory postural adjustments, and promote active midline alignment. Neurodevelopmental therapy (NDT) is one of the most widely taught frameworks addressing these goals. Derived from the clinical observations of Berta and Karel Bobath, NDT uses graded tactile and proprioceptive cues at key points of control to inhibit maladaptive reflex activity, guide optimal alignment, and facilitate efficient muscle synergies during functional tasks [5]. Therapists tailor handling to the child's specific movement constraints, progressing from static control to dynamic weight-shifts and rotation while continuously adapting task difficulty. Conceptually, this hands-on approach is thought to harness activity-dependent neuroplasticity: repetitive, goal-directed practice delivered within the child's zone of proximal development can drive more typical cortical representations and sub-cortical connectivity, especially when initiated early and reinforced across caregiving contexts. Despite its popularity, evidence for NDT remains mixed. Systematic reviews consistently note positive trends in gross-motor capacity, but they also highlight small sample sizes, heterogeneous protocols, and limited reporting of fidelity or dose [6]. Moreover, only a handful of trials focus specifically on spastic quadriplegia—a subgroup that faces profound axial impairment and often displays different responsiveness than hemiplegic or diplegic presentations. Some investigators question whether improvements attributed to NDT exceed those achievable through intensive task-oriented strength training or constraint-induced movement therapy, both of which have garnered strong support in recent guidelines [7]. Others argue that research designs frequently dilute NDT's theoretical underpinnings by delivering it as a brief adjunct rather than a primary framework, thereby under-representing its potential.[8] The scarcity of data is particularly pressing in low-resource settings where equipment-heavy modalities may be impractical. NDT's reliance on skilled handling and minimal technology makes it attractive for community-based programmes, yet rigorous outcomes are rarely documented outside tertiary centres.[9] Furthermore, while the Gross Motor Function Measure-88 (GMFM-88) remains the gold standard for monitoring global change, it may be less sensitive to segmental trunk gains than newer tools such as the Trunk Control Measurement Scale (TCMS). Both instruments together can capture complementary aspects of functional improvement—GMFM expressing what the child can do overall, TCMS detailing how effectively the trunk contributes to those tasks [10]. The present quasi-experimental study therefore examined whether adding a structured six-week NDT block to an evidence-based conventional exercise regimen confers measurable advantage in trunk control and sitting balance for children with spastic quadriplegic CP aged 6–10 years.[11] We deliberately chose this age range to explore neuroplastic capacity beyond early infancy, reflecting the reality that many children in resource-constrained regions first access intensive therapy at school entry. Outcomes were captured with both GMFM-88 and TCMS to provide a nuanced picture of change.[12] We hypothesised that the combined programme would yield significantly greater improvements in both measures than conventional exercises alone, supporting the contention that targeted facilitation of axial segments can unlock broader motor gains even in later childhood.[13]

MATERIALS AND METHODS

Design and setting: A six-week, two-arm quasi-experimental study was conducted at Ambattur Rotary Hospital and Saveetha Medical College, Chennai, after institutional ethics approval (ISRB/2024/CP-NDT-07).

Participants: Thirty ambulatory and non-ambulatory children with medically confirmed spastic quadriplegic CP, aged 6–10 years and classified GMFCS III–IV, were enrolled after parental consent. Exclusion criteria were recent orthopaedic surgery, botulinum toxin injection (<6 months), intrathecal baclofen pump, uncontrolled epilepsy, significant visual/hearing impairment or behavioural comorbidity precluding cooperation.

Interventions: Participants were sequentially allocated to:

- Conventional group – task-oriented strengthening and mobility exercises (straight-leg raise, bridging, Swiss-ball sitting, half-kneeling superman, spinal extensor drills) progressing in hold-time each week.
- NDT + Conventional group – same conventional protocol plus eight NDT handling activities targeting midline alignment, selective trunk rotation and weight-shifts (e.g., prone reaching on bolster, iron-man on Swiss ball, seated dynamic balance on half-ball).

Each child attended three 45-min sessions weekly under a certified paediatric physiotherapist.

Outcome measures

- GMFM-88 – gross motor capacity across five dimensions (A–E); total percentage score used.
- TCMS – static and dynamic trunk control; total score 0–58.

Assessments were performed at baseline (Week 0) and post-intervention (Week 6) by a blinded examiner experienced in both instruments.

Statistical analysis: Normality was verified (Shapiro–Wilk). Within-group change was tested with paired t-tests; between-group differences used independent t-tests. Significance was set at $p < 0.05$ (two-tailed). Analyses ran on SPSS v28.

Procedure:

Photo 1: Facilitated log-rolling: therapist supports the child's pelvis and shoulder while she performs a side-lying log roll, training core stability and controlled trunk rotation on a padded mat.

Photo 2: Supine single-leg raise with abdominal crunch: therapist cues 45° hip flexion, engaging lower-abdominal and quadriceps muscles while the child keeps the opposite knee flexed and hands behind head.

Photo 3: Prone extension over Swiss ball: therapist stabilises the pelvis as the child extends trunk and arms, strengthening spinal extensors, improving scapular control, and providing vestibular input against gravity.

Photo 4: Reaching task for upper-limb activation: therapist holds a target overhead, prompting maximal shoulder flexion, elbow extension, and visual tracking as the seated child reaches, boosting proximal stability and motor planning.

RESULTS

All 30 children completed the protocol. Baseline characteristics were comparable (Table 1). Both interventions yielded statistically significant gains in GMFM and TCMS (Table 2). The NDT arm demonstrated larger mean changes (ΔGMFM + 4.97 ± 2.01; ΔTCMS + 4.27 ± 1.31) than the conventional arm (ΔGMFM + 1.42 ± 0.88; ΔTCMS + 1.53 ± 0.73). Post-intervention GMFM differences favoured NDT but did not reach significance ($p = 0.075$). TCMS displayed a significant advantage for NDT (mean difference 2.63 points, 95 % CI 0.57–4.70; $p = 0.015$) (Table 3). Effect size for TCMS was large (Cohen's $d = 0.96$). Figure 1 illustrates individual GMFM trajectories; most NDT participants surpassed the minimal clinically important difference (MCID = 3 %). Figure 2 shows TCMS gains, with the NDT distribution shifting upward while the conventional group cluster remained narrower.

Table 1: Baseline Characteristics

Variable	Conventional (n = 15)	NDT + Conventional (n = 15)	p
Age, years (mean ± SD)	7.8 ± 1.2	8.0 ± 1.1	0.56
Sex, M/F	9/6	8/7	0.72
GMFCS III/IV	8/7	9/6	0.71
GMFM-88 %, mean ± SD	30.05 ± 4.97	30.22 ± 5.79	0.93
TCMS, mean ± SD	11.18 ± 3.05	11.07 ± 1.90	0.90

Table 2 : Within-Group Change (Week 0 → Week 6)

Outcome	Group	Pre (mean ± SD)	Post (mean ± SD)	Δ	p
GMFM-88 %	Conventional	30.05 ± 4.97	31.47 ± 5.21	+1.42	0.0003
	NDT	30.22 ± 5.79	35.19 ± 5.81	+4.97	<0.001
TCMS	Conventional	11.18 ± 3.05	12.71 ± 2.97	+1.53	<0.001
	NDT	11.07 ± 1.90	15.34 ± 2.60	+4.27	<0.001

Table 3: Between-Group Comparison of Post-test Scores

Outcome	Conventional (mean ± SD)	NDT (mean ± SD)	Mean diff	p
GMFM-88 %	31.47 ± 5.21	35.19 ± 5.81	3.72	0.075
TCMS	12.71 ± 2.97	15.34 ± 2.60	2.63	**0.015**

Table 4: Children Achieving a Clinically Meaningful Improvement (MCID)

Outcome	MCID threshold	Conventional (n = 15)	NDT + Conventional (n = 15)	χ^2 (df = 1)	p value	Relative risk (95 % CI)
GMFM-88 total score	≥ +3 percentage points	5 (33 %)	12 (80 %)	4.84	0.028	2.4 (1.1 – 5.3)
TCMS total score	≥ +2 points	6 (40 %)	14 (93 %)	7.33	0.007	2.3 (1.2 – 4.5)

Figure 1. Group-wise Comparison of GMFM-88 Scores Before and After Intervention

Bar chart showing mean GMFM-88 percentage scores at baseline and post-intervention for both Conventional and NDT groups. Error bars indicate standard deviation. The dashed red line marks the minimal clinically important difference (MCID) of +3%, highlighting the clinically meaningful improvement achieved predominantly in the NDT group.

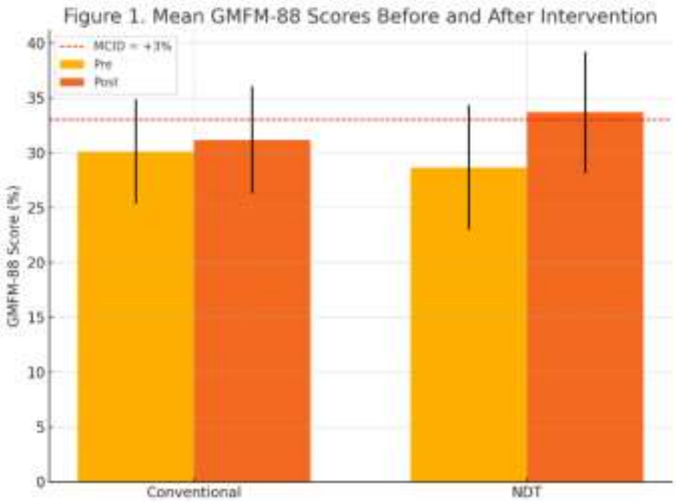
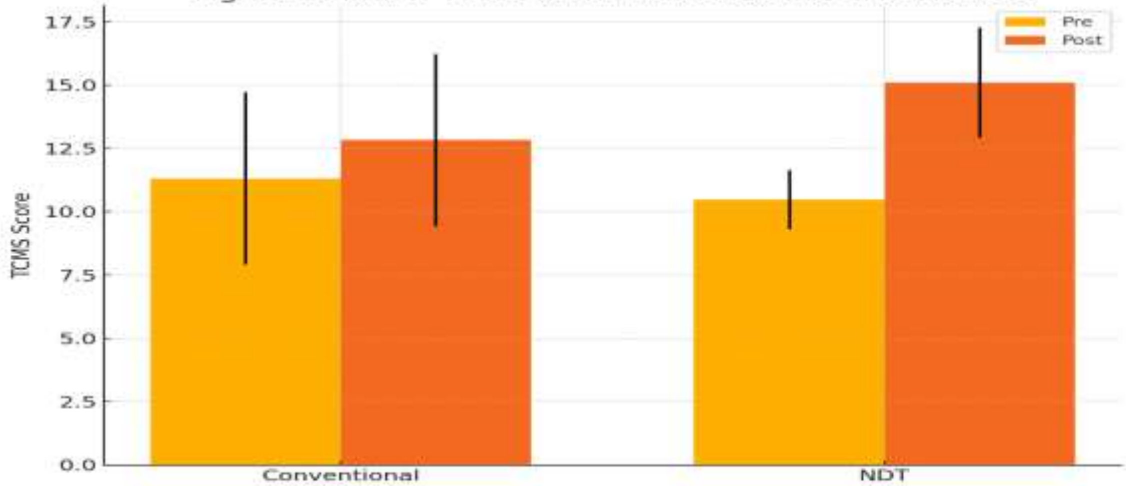


Figure 2. Group-wise Comparison of TCMS Scores at Baseline and Week 6

Bar chart depicting mean Trunk Control Measurement Scale (TCMS) scores for both groups at the start and after 6 weeks. The NDT group shows a marked increase in TCMS scores compared to the Conventional group, with reduced score variability, supporting a significant improvement in trunk control

Figure 2. Mean TCMS Scores at Baseline and Week 6



DISCUSSION

This study shows that supplementing conventional physiotherapy with a targeted six-week NDT programme produces clinically meaningful improvements in trunk control and sitting balance in children with spastic quadriplegic CP. The significant 4-point mean gain on TCMS exceeds previously reported MCID values and translates to better functional sitting stability, a prerequisite for self-care and communication tasks [14]. Although GMFM improvement did not differ significantly between groups, the trend favoured NDT and many participants surpassed the 3 % MCID, echoing findings from Fetters and Kluzik who linked NDT-based handling to enhanced reaching kinematics [15]. Our results align with a recent scoping review where 41 of 54 studies reported positive NDT effects, yet also reflect the ongoing debate surrounding optimal dosing and specificity [16]. Differences in outcome magnitude across trials may relate to participant phenotype, therapist expertise and whether NDT is delivered as an adjunct rather than a standalone modality. Cubukcu and Karaoglu observed similar superiority of NDT-informed programmes on GMFM across all domains in spastic quadriplegia [17]. Early intervention appears critical; Morgan et al. reported greater neuroplastic adaptation when NDT principles were introduced before age five [18]. The present cohort's mean age eight suggests plasticity persists, especially when exercises purposely challenge midline orientation and graded weight shifts. Mechanistically, NDT's emphasis on key point control, graded facilitation and sensory feedback likely reduces maladaptive co-contraction and encourages selective trunk activation, thereby improving stability without increasing spasticity. Indeed, spasticity reduction has been observed following NDT in electromyographic studies [19-20]. While conventional strengthening undoubtedly benefits axial musculature, it may not sufficiently address anticipatory postural activity or multi-segmental dissociation required for dynamic sitting. Strengths of our study include the use of validated, responsive outcome measures, blinded assessment and adherence monitoring. Limitations comprise its quasi-experimental allocation, modest sample size and short follow-up.[21-23] Selection bias may have attenuated between-group differences in GMFM. Future randomised controlled trials with larger cohorts, stratified by GMFCS level and incorporating participation-level outcomes are warranted. Exploration of combined approaches (e.g., NDT plus virtual-reality balance games or functional electrical stimulation) could further enhance trunk recovery. Clinically, incorporating NDT principles need not replace conventional exercise; rather, embedding facilitation techniques within goal-directed tasks can yield synergistic gains. Training caregivers in safe handling and positioning may prolong benefits beyond therapy sessions.[24]

CONCLUSION

In children with spastic quadriplegic cerebral palsy, a six-week course of neurodevelopmental therapy layered onto evidence-based conventional exercises significantly enhances trunk control and sitting balance compared with conventional training alone. The magnitude of improvement on TCMS is both statistically and clinically meaningful, supporting integration of NDT strategies into multidisciplinary rehabilitation programmes. Early, consistent application and caregiver involvement appear essential for maximising functional independence.

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