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Modulating Tone to Promote Motor Development Using a Neurofacilitation of Developmental Reaction (NFDR) Approach in Children with Neurodevelopmental Delay

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Abstract

***Objective*: To compare the efficacy of a Neurofacilitation of Developmental Reaction (NFDR) approach with that of a Conventional approach in the modulation of tone in children with neurodevelopmental delay.**

***Methods:* Experimental control design. A total of 30 spastic children ranging in age from 4 to 7 years with neurodevelopmental delay were included. Baseline evaluations of muscle tone and gross motor functional performance abilities were performed. The children were allocated into two intervention groups of 15 subjects each. In groups A and B, the NFDR and conventional approaches were applied, respectively, for 3 months and were followed by subsequent re-evaluations.**

***Results:* Between group analyses were performed using independent t test for tone and primitive reflex intensity and a Mann-Whitney U test for gross motor functional ability. For the within-group analyses, paired t tests were used for tone and primitive reflex intensity, and a Wilcoxon signed-rank test was used for gross motor functional ability.**

***Conclusion:* The NFDR approach/technique prepares the muscle to undergo tonal modulation and thereby enhances motor development and improves the motor functional performance abilities of the children with neurodevelopmental delay.**

Keywords: *neurodevelopmental delay, motor skills, muscle tone, posture, neurofacilitation of developmental reaction*

Introduction

Muscle tone is the slight constant tension of healthy muscles and contributes a slight resistance to the passive displacement of a limb. Muscle tone is directly related to a child's inherent neural wiring through which the brain perceives the positions of the muscles. Tone reflects the maturation of the central nervous system. With an intact neuromuscular system, the muscles can adjust to immediate postural or limb changes and maintain a child's posture and arm and leg positions against gravity. The primary purpose of muscle tone is to keep the muscles primed and ready for action to maintain posture, balance and equilibrium. Muscle tone in combination with primitive reflexes directly influences early motor development (1). The "primitive reflexes" appear and disappear in an expected order during infant development. The failure of these reflexes to appear at appropriate ages or their persistence beyond appropriate ages of disappearance is indicative of neurodevelopmental delay (2).

In children with neurodevelopmental delay (cerebral palsy), the primitive reflexes persist and interfere with normal motor development (3). These children are unable to acquire normal motor skills due to abnormal muscle tone and persistent primitive reflexes and thus exhibit abnormal motor reflexes, asymmetrical responses, and impaired coordination of muscle action. Hence, assessments of muscle tone and primitive reflex status are crucial parts of motor examinations and the formulation of intervention strategies for children with neurodevelopmental delay (3,4).

Among the available conventional intervention techniques, which include the Rood approach, Vojta therapy, neurodevelopmental therapy (NDT) and sensory integration, NDT is the most widely accepted. These techniques primarily emphasise the normalisation of muscle tone, stretching, positioning, improving, and correcting posture (via stretching and specialized methods of handling), weight bearing, and weight shifting in developmentally appropriate positions, but they do not incorporate the principles of tone modulation and postural and movement dynamics (5–7) as elementary units of intervention.

Recently, a new technique termed Neurofacilitation of Developmental Reaction (NFDR) has evolved. This technique incorporates the dynamics of movement and postural control as elementary units of the intervention. The current study aimed to compare the Primitive Reflex Intensity Grading (PRIG), Gross Motor Functional Measure (GMFM), and Gross Motor Functional Classification System (GMFCS) scores between Neurofacilitation of Developmental Reaction (NFDR) and conventional therapy (CT) groups in terms of the modulation of tone.

Subjects and Methods

In the present study, 46 children with neurodevelopmental delay (cerebral palsy) were screened for inclusion in this clinical trial of 30 children. The children with mild to moderate spasticity within the age range 4 to 7 years and with IQs of 55 or above were included. Those with severe to profound mental retardation, dystonic presentation, contractures, and deformities and sensory impairments were excluded from the study. Ethical clearance and approval were obtained from the institutional human ethical research committee, and informed consent was obtained from the parents (or guardians) at the time of enrolment. After enrolment, baseline evaluations of muscle tone using the Modified Ashworth Score, primitive reflexes status using the primitive reflex intensity grading (PRIGS) and functional status using the Gross Motor Functional Measure (GMFM) were performed (6,7).

After the baseline evaluations, the children were randomly allocated into two intervention groups (i.e., groups A B) using a computer-generated allocation sequence (Ralloc software). The Neurofacilitation of Developmental Reaction (NFDR) approach was applied in group A,(6-7), and a conventional technique was applied in group B. The interventions were applied over a period of 3 months. Re-evaluations were performed at three months. The durations and frequencies of all sessions were kept constant at 3 40 minute sessions per week.

Treatment protocol

The children participated in one of the two above mentioned intervention groups.

Neurofacilitation of Developmental Reaction (NFDR) approach

The Neurofacilitation of Developmental Reaction (NFDR) approach ,(6-7)is based on the principles of postural dynamics and aims to elicit an adaptive postural response. The intervention has two phases.

Preparatory and Variability Phase: In this phase, the preparatory component seeks to normalise the tonal characteristics, increase the passive and active mobilities of the body structure and promote symmetry and alignment via facilitatory and inhibitory techniques and positioning. The Variability component seeks to elicit static and dynamic postural responses and promote postural stability and task related performances by the altering spatial and temporal characteristics of a support surface configuration using neurofacilitatory orientations of the bodily segments (with reference to the trunk) and limb manoeuvres to augment the central stability, normalise tone and facilitate/reinforce normal motor behaviour.

Modulation Phase: This phase aims to modulate muscle tone and primitive reflex behaviours by altering interaction dynamics and perturbation characteristics (at varying degrees, angles and intensities). This phase incorporates the principles of movement dynamics to regulate tonal behaviour using neuro-facilitatory contact points, vestibular, proprioceptive and kinaesthetic inputs (as key elements in training motor control), recruitment of the trunk musculature and integration of the developmental reflexes to provide a variety of exposures that enable the learning of movement experiences and thereby influence and promote motor development.

Conventional therapy (CT)

The conventional treatment incorporated positioning and handling at key therapeutic points with inhibitory and facilitatory techniques (such as the use of developmental positions, stretching exercises, etc.) and weight shifting and weight bearing in developmental positions.

Statistical Analysis

To compare the groups, the pre- and post-intervention scores were used for the analyses. Independent t tests were performed on the symmetrically distributed variables, i.e., tone and primitive reflex intensity, for the between-group comparisons (NFDR vs CT group, pre- and post-intervention), and paired t tests were performed for the within-group comparisons (i.e., pre- vs post-intervention within the NFDR group and pre- vs post-intervention within the CT group). For asymmetrically distributed variables, i.e., the gross motor functional abilities (GMFM and GMFCS scores), non-parametric Mann–Whitney U tests were used for the between-group comparisons, and Wilcoxon signed-rank tests were used for the within-group analyses. We used the means and standard deviations to describe the PRIG and tone scores and the medians and interquartile ranges for the GMFM and GMFCS scores. A *P* value < 0.05 was considered as statistically significant.

Results

All 30 subjects were analysed in terms of tone, primitive reflexes status and gross motor functional abilities.

Between-Group Comparison

We compared the mean scores of the Neurofacilitation of Developmental Reaction and the Conventional Therapy groups at the pre-intervention and post-intervention phases in terms of muscle tone, primitive reflex intensity and the gross motor functional measures.

At baseline, there were no significant differences between the NFDR and CT groups in the variables of tone and primitive reflex intensity. The means (SD) and *P* values are illustrated in table 1. Table 2 shows that at 3 months, there were significant differences in tone between the NFDR CT groups in the right forearm (*P* = 0.021), the left and right hips (*P* = 0.006 and 0.009, respectively), the left and right knees (*P* = 0.018 and 0.025, respectively) and the right ankle (*P* = 0.010). The difference in the primitive reflexes intensity scores (*P* = 0.394) between the NFDR and CT groups was not significant.

Nonparametric tests were used to analyse the GMFM and the GMFCS level. The medians, IQs and *P* values were calculated. At baseline there were no significant differences between the NFDR and CT groups in the percentage dimension (GMFM) score or the GMFCS level; however, at 3 months, the *P* values indicated significant differences in favour of the NFDR group in both the percentage dimension (GMFM) score and the GMFCS level (*P* = < 0.001 and 0.01, respectively).

Table 1: Comparison of Tone (Upper & Lower Extremity) & Primitive Reflex Intensity, NFDR vs CT group (pre-intervention)

Pre-Intervention	Shoulder		Elbow		Forearm		Wrist		Hip		Knee		Ankle		PRIG* [a]
	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	
NFDR group	88.9 (13.5)	94.2 (10.3)	88.0 (12.6)	92.7 (9.6)	85.3 (13.0)	90.0 (12.0)	90.7 (11.6)	96.0 (7.4)	76.4 (9.6)	80.7 (11.9)	76.7 (12.3)	80.7 (14.4)	74.4 (12.5)	77.3 (13.3)	74.2 (6.1)
CT group	93.1 (9.2)	93.6 (9.6)	90.0 (12.0)	91.3 (10.6)	88.0 (12.6)	88.0 (12.1)	94.0 (10.6)	94.0 (10.6)	80.9 (9.7)	81.3 (9.9)	80.0 (13.1)	80.7 (13.3)	78.0 (13.2)	76.7 (13.5)	74.4 (9.1)[a]
Test Statistics (df)	-1.0 (28)	0.2 (28)	-0.4 (28)	0.4 (28)	-0.6 (28)	0.5 (28)	-0.8 (28)	0.6 (28)	-1.3 (28)	-0.2 (28)	-0.7 (28)	0.0 (28)	-0.7 (28)	0.1 (28)	- 0.1 (28)
P Value (Between group)	0.325	0.856	0.660	0.721	0.574	0.652	0.418	0.552	0.217	0.869	0.479	1.000	0.483	0.893	0.944
Mean Difference	-4.2	0.7	-2.0	1.3	-2.7	2.0	-3.3	2.0	-4.4	-0.7	-3.3	0.0	-3.3	0.7	-0.2

Statistical analyses were conducted using, [b] Independent *t* test; PRIG*=Primitive Reflex Intensity Grade
Data are expressed in [a] mean (standard deviation)

Table 2: Comparison of Tone (Upper & Lower Extremity) & Primitive Reflex Intensity, NFDR vs CT group (Post-intervention)

Post-Intervention	Shoulder		Elbow		Forearm		Wrist		Hip		Knee		Ankle		PRIG* [a]
	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	Left [a]	Right [a]	
NFDR group	97.1 (4.9)	99.0 (2.8)	96.4 (6.3)	99.3 (2.7)	96.4 (6.3)	98.6 (5.3)	97.9 (4.3)	99.3 (2.7)	94.8 (5.7)	95.0 (6.1)	93.6 (6.3)	94.3 (6.5)	89.3 (6.2)	91.4 (6.6)	77.4 (1.4)
CT group	95.2 (8.5)	95.5 (9.3)	94.4 (9.4)	94.3 (10.9)	90.7 (10.7)	90.7 (10.7)	97.1 (6.1)	96.4 (7.4)	86 (9.4)	86.9 (8.8)	83.6 (13.4)	83.6 (15.5)	82.9 (12.7)	81.4 (11.7)	75.6 (7.3)
Test Statistics (df)	0.7 (26)	1.4 (26)	0.7 (26)	1.7 (26)	1.7 (26)	2.5 (26)	0.4 (26)	1.4 (26)	3.0 (26)	2.8 (26)	2.5 (26)	2.4 (26)	1.7 (26)	2.8 (26)	0.9 (26)
P Value (Between group)	0.475	0.180	0.485	0.107	0.098	0.021	0.723	0.188	0.006	0.009	0.018	0.025	0.100	0.010	0.394
Mean Difference	1.0	3.6	2.1	5.0	5.7	7.9	0.7	2.9	8.8	8.1	10.0	10.7	6.4	10.0	1.7

Statistical analyses were conducted using,
[a] Independent t test; PRIG* = Primitive Reflex Intensity Grade
Data are expressed in a mean (standard deviation)

Within-group comparisons (i.e., pre- vs post-intervention) for the NFDR and CT groups were also performed. Within the NFDR group, the p values indicated significant differences in the variables of tone in left and right shoulders (*P* = 0.003 and 0.037, respectively), left and right elbows (*P* =0.001 and 0.006, respectively), left and right forearms (*P* = < 0.001 and.002, respectively), left wrist (P = 0.006), left and right hips (*P* = < 0.001 and < 0.001, respectively), left and right knees (*P* = < 0.001 and < 0.001, respectively) and left and right ankles (*P* = < 0.001 and < 0.001, respectively) and in the GMFM score and GFCS level (*P* = 0.001 and < 0.001, respectively). In CT group, the *P* values indicated significant differences only for the variables of tone in left the right shoulders (*P* = 0.029 and.028, respectively), left and right hips (*P* = <0.001 and <0.001, respectively), left knee (*P* = 0.04) and left and right ankles (*P* = 0.019 and 0.019, respectively) and the GMFCS level (*P* = 0.001)

Discussion

The NFDR approach group exhibited greater improvements in muscle tone, primitive reflexes and gross motor functional measures.

The significant differences in tone between the groups suggest that the NFDR group exhibited significant improvements. In its primary phase (i.e., the preparatory and variability phase), the NFDR technique modulated the internal mechanisms of the tonal characteristics by varying the relative configuration of body segments (altering and grading positioning mechanics) and regulating muscle stiffness (via differential loading of the body segments). Moreover, the muscle recruitment was performed synergistically via neuromuscular procedures and techniques by altering positioning mechanics and varying support surface configurations and their dynamic characteristics in response to external stimuli. This in turn improved the activation thresholds of the postural and segmental muscles. The altered positioning mechanics and varied support surface configurations helped in the generation of direction-specific postural behaviours and the integration of vestibular, proprioceptive and labyrinthine input in a graded fashion (6–8) . This optimum sensory input also helped to minimise muscle stiffness at the neural level and thereby promoted optimal muscle behaviour, which accounted for the changes in muscle tone and reflex behaviours.

The significant differences in the behaviour results in the NFDR group can be attributed to tonal changes, greater sensorimotor variabilities provided by the support surface configurations and the relative orientations of the body segments, which placed mechanical and neural demands on CNS and thereby regulated the vestibular, otolithic, proprioceptive, and labyrinthine inputs. The sensory input regulation helped to provide qualitative information about the dynamics of the body. The selected sensory modalities were tuned to the task demands by the task/environmental manipulations (9–11). These manipulations helped in the generation of voluntary muscle behaviour and thereby modulated the stereotyped reflex behaviour (12–13).

Table 3: Comparison of GMFM %age Dimension Score and GMFCS Level (Pre-intervention and Post-intervention)

Variable	GMFM %age Dimension Score [c]		GMFCS Level [c]	
	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
NFDR group (n=15)	41.8(17.8)	88.3(17.6)	3.0(1.0)	1.0(1.0)
CT group (n=15)	41.0(36.8)	48.9(34.0)	3.0(2.0)	3.0(1.0)
Test Statistics (df)	-0.2(28)	-3.5(28)	-0.8(28)	-3.4(28)
P Value (Between Group)	0.852	<.001	0.419	0.001
Mean Difference	0.852	<.001	0.419	0.001

Statistical analyses were conducted using
[c] Z statistics (Mann Whitney U test)
Data are expressed in c median (interquartile range)

Table 4: Comparison of Tone (Upper and Lower Extremity) and Primitive Reflex Intensity, within NFDR group (Pre- and Post-intervention)

Timeline	Shoulder		Elbow		Forearm		Wrist		Hip		Knee		Ankle		PRIG* [b]
	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	
Baseline	88.1 (13.6)	93.8 (10.6)	87.1 (12.7)	92.1 (9.7)	84.3 (12.8)	89.3 (12.1)	90.0 (11.8)	95.7 (7.6)	75.7 (9.5)	80.2 (12.2)	76.4 (12.8)	80.7 (14.9)	73.6 (12.2)[a]	76.4 (13.4)	74.1 (6.4)
3 Months	97.1 (4.9)	99.0 (2.8)	96.4 (6.3)	99.3 (2.7)	96.4 (6.3)	98.6 (5.3)	97.9 (4.3)	99.3 (2.7)	94.8 (5.7)	95.0 (6.1)	93.6 (6.3)	94.3 (6.5)	76.4 (13.4)	91.4 (6.6)	77.4 (1.)4
Test Statistics (df)	3.6 (13)	- 2.3 (13)	-4.2 (13)	-3.2 (13)	-5.1 (13)	-3.8 (13)	-3.3 (13)	-2.1 (13)	-15.0 (13)	-6.1 (13)	-7.8 (13)	-5.0 (13)	89.3 (6.2)[a]	-6.6 (13)	-1.9 (13)
P Value (Between group)	0.003	0.037	0.001	0.006	<.001	0.002	0.006	0.055	<.001	<.001	<.001	<.001	91.4 (6.6)	<.001	0.075
Mean Difference	-9.0	-5.2	-9.3	-7.1	-12.1	-9.3	-7.9	-3.6	-19.0	-14.8	-17.1	-13.6	-6.9 (13)[b]	-15.0	-3.2

Statistical analyses were conducted using
[b] Paired t test; PRIG*=Primitive Reflex Intensity Grade
Data are expressed in a mean (standard deviation)

Table 5: Comparison of Tone (Upper & Lower Extremity) and Primitive Reflex Intensity, within CT group (Pre-post intervention)

Timeline	Shoulder		Elbow		Forearm		Wrist		Hip		Knee		Ankle		PRIG* [b]
	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	Left [b]	Right [b]	
Baseline	93.6 (9.4)	94.0 (9.8)	90.7 (12.1)	92.1 (10.5)	88.6 (12.9)	88.6 (12.3)	95.0 (10.2)	95.0 (10.2)	81.2 (10.0)	81.7 (10.2)	80.7 (13.3)	81.4 (13.5)	79.3 (12.7)	77.9 (13.1)	74.1 (9.4)
3 Months	95.2 (8.5)	95.5 (9.3)	94.3 (9.4)	94.3 (10.9)	90.7 (10.7)	90.7 (10.7)	97.1 (6.1)	96.4 (7.4)	86.0 (9.4)	86.9 (8.8)	83.6 (13.4)	83.6 (15.5)	82.9 (12.7)	81.4 (11.7)	75.6 (7.3)
Test Statistics (df)	-2.5 (13)	-2.5 (13)	-2.1 (13)	-1.9 (13)	-1.4 (13)	-1.4 (13)	-1.9 (13)	-1.5 (13)	-7.1 (13)	-6.3 (13)	-2.3 (13)	-1.9 (13)	-2.7 (13)	-2.7 (13)	-1.4 (13)
P Value (Between group)	0.029	0.028	0.055	0.082	0.189	0.189	0.082	0.165	<.001	<.001	0.040	0.082	0.019	0.019	0.187
Mean Difference	-1.7	-1.4	-3.6	-2.1	-2.1	-2.1	-2.1	-1.4	-4.8	-5.2	-2.9	-2.1	-3.6	-3.6	1.1

Statistical analyses were conducted using
[b] Paired t test; PRIG*=Primitive Reflex Intensity Grade
Data are expressed in a mean (standard deviation)

Table 6: Comparison of GMFM %age Dimension Score and GMFCS Level within NFDR & CT group (Pre-intervention & Post-intervention)

Timeline	NFDR group		CT group	
	GMFM %age Dimension Score [d]	GMFCS Level [d]	GMFM %age Dimension Score [d]	GMFCS Level [d]
Baseline	41.8(17.8)	3.0(1.0)	41.0(36.8)	3.0(2.0)
3 Months	88.3(17.6)	1.0(1.0)	48.9(34.0)	3.0(1.0)
Test Statistics (df)	-3.3(14)	-3.7(14)	-1.3(14)	-3.3(14)
P Value (Between Group)	0.001	<0.001	0.18	0.001

Within group Statistical analyses were conducted using
[d] Wilcoxon Sign Rank test
Data are expressed in median (interquartile range)

Hence, the modulations of the tone and integration of the primitive reflexes augmented the gross motor functional abilities (i.e., the GMFM and GMFCS outcomes), and these qualitative responses were apparently due to the variability of the motor and postural behaviours within the NFDR group.

Conclusion

The neurofacilitation of Developmental Reaction (NFDR) technique prepares the muscles to undergo tonal modulation and thereby enhances motor development and enables gross motor functional performance abilities in children with neurodevelopmental delay.

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Conflicts of Interest

None

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Authors' Contributions

Conception and design, analysis and interpretation of the data, final approval of the article: VB, MB
Drafting of the article: VB, MB, VPS
Critical revision of the article for the important intellectual content: VB, MB, RMP, VPS, GGA
Provision of study materials or patient, administrative, technical or logistic support: VPS
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