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EFFECTS OF NEURODEVELOPMENTAL THERAPY ON FUNCTION AND MUSCLE ULTRASOUND PARAMETERS IN CHILDREN WITH CEREBRAL PALSY

ORIGINAL ARTICLE

ABSTRACT

Purpose: This study aimed to evaluate the effectiveness of neurodevelopmental therapy (NDT) for improving lower extremity functions, ankle dorsiflexion range of motion (ROM), popliteal angle, medial gastrocnemius (GCM) muscle thickness (MT), and functionality of lower extremity on children with hemiparetic Cerebral Palsy (CP).

Methods: Eighteen children with hemiparetic CP aged between 6-15 years were included in the study. Structured NDT (s-NDT) was applied 40 minutes per session, three times a week over 12 weeks. Children were evaluated with Gross Motor Function Measurement-88 (GMFM-88) for motor function level; with goniometer for ankle dorsiflexion ROM and popliteal angle; with ultrasound for medial GCM MT, and with ultrasound Lower Extremity Function Test (LEFT) for the functionality of lower extremity. Children were evaluated before and after the intervention.

Results: After the treatment, statistically significant differences were obtained in mean values of GMFM-88, ankle dorsiflexion ROM, medial GCM MT, and LEFT ($p<0.05$). There was no significant difference in popliteal angle ($p>0.05$).

Conclusion: In conclusion, it was observed that s-NDT might be effective on motor function level, ankle dorsiflexion, medial GCM MT, and lower extremity functionality in children with hemiparetic CP. These improvements will make significant positive contributions to the mobility of children.

Key Words: Cerebral Palsy, Hemiparesis, Lower Extremity, Neurodevelopmental Therapy, Ultrasonographic Imaging.

NÖROGELİŞİMSEL TEDAVİNİN SEREBRAL PALSİ'Lİ ÇOCUKLARDA FONKSİYONELLİK VE KAS ULTRASON PARAMETRELERİNE ETKİSİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu çalışmanın amacı; hemiparetik serebral palsi (SP)'li çocuklarda nörogelişimsel tedavinin (NGT) alt ekstremite fonksiyonları, ayak bileği dorsifleksiyon eklem hareket açıklığı (EHA), popliteal açı, medial gastroknemius (GCM) kas kalınlığı (MT) ve alt ekstremiye fonksiyonelliğini iyileştirmedeki etkinliğini değerlendirmekti.

Yöntem: Çalışmaya yaşları 6-15 yıl aralığında on sekiz hemiparetik SP'li çocuk dahil edildi. Yapılandırılmış NGT haftada 3 seans, her seans 40 dakika olacak şekilde 12 hafta boyunca uygulandı. Çocukların motor fonksiyon seviyelerini değerlendirmek için Kaba Motor Fonksiyon Ölçütü-88 (KMFÖ-88), ayak bileği dorsifleksiyon açısı ve popliteal açının değerlendirmesi için universal gonyometre, medial gastroknemius kasının kalınlığı ölçmek için ultrasanografik ölçüm ve alt ekstremite fonksiyonlarını değerlendirmek için Alt Ekstremite Fonksiyon Testi (AEFT) kullanıldı.

Sonuçlar: Tedavi sonrasında GMFM-88, ayak bileği dorsifleksiyon EHA, medial GCM MT ve AEFT değerlerinde istatistiksel olarak anlamlı gelişme olduğu belirlendi ($p<0,05$). Popliteal açı değerlerinde ise anlamlı değişiklik yoktu ($p>0,05$).

Tartışma: Sonuç olarak, hemiparetik SP'li çocuklarda yapılandırılmış NGT'nin motor fonksiyon düzeyi, ayak bileği dorsifleksiyonu, medial GCM- MT değerleri ve alt ekstremite fonksiyonelliği üzerine olumlu etkileri olabileceği gözlendi. Elde edilen bu gelişmeler çocukların mobilitesine önemli pozitif katkılar sağlayacaktır.

Anahtar Kelimeler: Serebral Palsi, Hemiparezi, Alt Ekstremite, Nörogelişimsel Tedavi, Ultrasonografik Görüntüleme.

INTRODUCTION

Cerebral palsy (CP) is a non-progressive developmental disorder characterized by a lifelong mobility and posture deficit caused by a lesion during the prenatal, natal, or postnatal phase during brain development (1, 2). In low- and middle-income countries, it is the most common physical disability in children, with a 2.0 to 2.9 percent (3). Hemiparetic CP is a type of CP that affects one-half of the body's lower and upper extremities and the trunk and can be accompanied by visual sensory impairments, convulsions, cognitive problems, and motor problems (4). There is a tendency to fall to one side due to poor balance reactions. The unaffected side's stability and balance reactions are hyperactive, and the weight is carried more on the unaffected side while standing, while the affected side is compensated accordingly (5, 6). Basic motor abilities such as standing, walking, and standing on one leg are challenging for children with hemiparetic CP (1).

Neurodevelopmental Therapy (NDT)/Bobath is a problem-solving technique used to evaluate and treat people who have functional, motor, and postural impairments resulting from central nervous system injuries (7). Dr. Karel and Bobath developed the Bobath method, which has been utilized by therapists worldwide in CP rehabilitation for over 80 years. By promoting muscle activity through key control points guided by the therapist, the Bobath concept attempts to improve gross motor function and postural control(7). The Bobaths renamed their method to neurodevelopmental treatment (NDT) in 1960. Both names are used to describe the same intervention in the literature (8).

Even though physiotherapists have been using the NDT approach for decades, a recent systematic review suggests that the impact of NDT on children with cerebral palsy is still unclear (9). Because of methodological and intervention variations among studies and a lack of standards for outcome criteria, clinical data supporting the benefits of NDT in children with Hemiparetic CP is inadequate. Rehabilitative ultrasonography (RUSG) is a technique for providing objective feedback on the efficacy of NDT (10). In the review by Yeşilyaprak et al, there was a direct relationship between muscle volume and cross-sectional area of the muscle (10). The muscle thickness (MT) of the gastrocnemius muscle (GCM) is thinner in children with CP than in children who are developing typically, and there is a significant relationship between MT and functional level when evaluated by muscle volume, GMFM-88, GMFCS, and mobility area (11). Only a few studies have evaluated the effect of NDT on muscle thickness using US techniques (12). The purpose of this study was to evaluate the effects of NDT in terms of motor function level, ankle dorsiflexion range of motion (ROM), popliteal angle, medial gastrocnemius muscle thickness, and quality of life in children with hemiparetic CP.

METHODS

Participants

Participants were recruited among children with hemiparetic CP attending the Umran Medical Center, Istanbul, Turkey. The study was approved by the Istanbul Medipol University, Non-Interventional Clinical Research Ethics Committee (Approval number: 10840098-604.01.01-E.66352). All parents had signed a written informed consent form, and the study was conducted according to the principles of the Declaration of Helsinki. This study was concluded between April 2020-January 2021.

The inclusion criteria are defined as having been diagnosed with hemiparetic CP, being between 6-15 years old, having sufficient communication skills (Communication Function Classification System level I-III), and having GMFCS level I-II. The exclusion criteria are defined as having congenital malformations, having botulinum toxin (BOTOX) injection on GCM in the last six months, having a history of orthopedic surgery (lengthening the GCM and hamstring muscles) in the last six months, and having severe convulsion situations that cannot be controlled with drugs.

Outcome Measurements

All children were evaluated in terms of motor function level, ankle dorsiflexion ROM, popliteal angle, medial gastrocnemius MT, and quality of life before and after the intervention. A physiotherapist performed all evaluations and interventions, while a physiatrist provided ultrasound measurements.

Patient Assessment Form: Age, gender, affected bodyside (left-right), time of birth, use of assistive device-orthosis, Gross Motor Function Classification System (GMFCS) level, and family history were questioned and recorded in the 'Patient Assessment Form'.

Gross Motor Function Measurement-88: GMFM-88 standing (13 items), walking (19 items climbing stairs (5 items), subsections are used. The gross motor functions in these items were evaluated according to the degree of achievement. Each item was given scores between 0 and 3; 0 means that the activity cannot be performed at all, and three means the activity is performed 90-100%. The Turkish validity and reliability study of the GMFM-88 was conducted (13).

Range of motion: Passive lower extremity range of motion was measured with a universal goniometer with Kendall protocol. The ankle dorsiflexion ROM was measured with the hip and knee joints fully extended in the supine position. The pivot point was placed in the lateral malleolus, and the fixed arm was kept parallel to the lateral midline of the fibula. The movable arm was placed to follow the lateral midline of the fifth metatarsal bone. Measurements were repeated three times, and average values were recorded (14).

For popliteal angle: The knee was extended as much as possible while the children were lying in supine table-tilt positions (in 900 flexions of hip and knee). The lateral femoral epicondyle was chosen as the pivot point, and the fixed arm was held perpendicular to the floor lateral to the femur, while the movable arm followed the fibula laterally. The "popliteal angle" was defined as the missing angle from full extension (14).

MT measuring method: Medial GCM thickness was measured by ultrasound (GE logiq E 9, 2D- 3.5-15 MHz sound waves). The MT was determined by measuring the distance between the upper and lower muscular fascias that could be seen on the image (10). The thickness of the medial GCM was measured using transverse imaging. The GCM transverse images were acquired from the popliteal fossa at a distance of 25% of the tibial length. The children were placed prone, with their legs hanging over the edge, enabling for a resting ankle position. (Figure 2).

Lower Extremity Function Test (LEFT): This test includes activities in daily living that require using the lower extremities. Doing these activities is scored between 0 (not difficult) and 4 (unable); as the score of the test approaches 0 (zero), the functional level of the child increases (15). The total score was calculated by adding the scores from each item. Some test items were scored by testing the parents' responses (walking distance, cycling) and the remaining items personally.

Intervention

Structured NDT (s-NDT) was implemented to children with hemiparetic CP for 40 minutes per session, three times a week over 12 weeks. Children were treated only in our center during this process because rehabilitation centers and pools were closed owing to the pandemic.

NDT/Bobath: All of the children received neurodevelopmental therapy based on Bobath principles. Stretching and strengthening exercises are used to help regulate muscle tone, provide bilateral body image, assist sensory-perception-motor development, facilitate normal movements, and support the regulation of the agonist-antagonist muscle relationship. The exercises were tailored to the children's motor and cognitive levels and their sensory sensitivities. The following exercises were performed:

• Trunk elongation exercise (Myofacial releasing techniques and active reaching exercise)

• Balance exercises (Balance exercises were performed with one foot on the floor and the other on the physiotherapist's knee, with tactile and proprioceptive stimuli used to reach for the object.

• Weight transfer exercises (It was applied in every position from supine to standing in neurodevelopmental order, utilizing Bobath's handling techniques without allowing the tone to rise on the affected side,

• Pelvic stabilization exercises (Bridge exercises performed at different angles for pelvic control),

• The difficulty level of the therapy was changed in 3-week periods according to the adaptive response of the children. Families were advised to encourage

Table 1: Distribution of Demographic Data.

Age (years) (Mean ± SD)		*7.61 ± 2.30*
Weight (kg) (Mean ± SD)		*27.86 ± 9.66*
Height (cm) (Mean ± SD)		*120.33 ± 16.40*
Gender (n / %)	***Girl***	*11 / 61.1*
	Boy	*7 / 38.9*
Affected Extremity (n / %)	***Right***	*12 / 66.7*
	Left	*6 / 33.3*
Use of orthoses (n / %)	***Not using***	*8 / 44.4*
	Night AFO	*4 / 22.2*
	Daytime AFO	*6 / 33.3*
Time of birth (n / %)	***Premature***	*11 / 61.1*
	Term	*7 / 38.9*
GMFCS Level (n / %)	***Level I***	*11 / 61.1*
	Level II	*7 / 38.9*

SD: Standard Deviation, AFO: Ankle Foot Orthoses, GMFCS: Gross Motor Function Classification System

double-sided use as much as possible in daily life and increase quality movement with minimum support, with techniques shown in the skills of putting on and taking off shoes and climbing stairs.

Sample Size

The study's sample size was calculated using G*Power V3.1.9.2. The effect size (0.3±0.2) calculated from the studies in the literature with the method of the difference between two dependent variables was f=1.5. The calculations were based on an alpha level of 0.05 and a beta level of 20% at the desired power of 80%. Accordingly, a sample size of at least seven patients was estimated (12).

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics 25 (IBM Corp., Armonk, NY, USA). The values were reported as mean±-standard deviation. The normal distribution of variables was examined with the Shapiro-Wilk Test. The non-parametric tests were applied to the variables. Demographic data were analyzed for descriptive analysis and frequency. The Wilcoxon test was used for repeated measure comparisons. The significant difference value was accepted as $p<0.05$.

RESULTS

Twenty children with hemiparetic CP were included in this study. Two of them were excluded from the study because of botox injection (GCM). Our study was completed on 18 children with hemiparetic CP. The allocation was shown in Flow Chart (Figure 1).

The demographic characteristics of children are shown in Table 1. The mean age was 7.61 ± 2.30 years. Seven children were female. A total of 11 of 18 children were level I, 7 of them were level II in GMFCS.

Table 2: Comparison of Findings before and after Treatment in Children with Hemiparetic CP.

	Pre-treatment	**Post-treatment**	**Mean Difference**	**Confidence Interval**	**Effect size**	**p-value**
	Avg ± SD	**Avg ± SD**		**Lower to Upper**		
GMFM - 88	*77.56 ± 14.34*	*81.61 ± 12.54*	*-4.055*	*-5.927 to -2.183*	*0.551*	**0.001***
LEFT	*30.16 ± 14.75*	*27.50 ± 13.62*	*2.666*	*1.903 to 3.429*	*0.762*	**0.000***
Ankle DF	*4.33 ± 4.65*	*6.38 ± 4.28*	*-2.055*	*-2.949 to -1.161*	*0.581*	**0.002***
PA	*19.88 ± 6.43*	*18.77 ± 5.87*	*1.111*	*-0.069 to 2.291*	*0.188*	*0.052*
GCM - MT (affected)	*11.01 ± 1.10*	*11.52 ± 1.01*	*-0.510*	*-0.633 to -0.386*	*0.817*	**0.000***
GCM - MT (non-affected)	*11.96 ± 1.34*	*12.29 ± 1.24*	*-0.336*	*-0.448 to -0.224*	*0.703*	**0.000***

*GMFM-88: Gross Motor Function Measurement - 88, LEFT: Lower Extremity Functionality Test, DF: Dorsiflexion, PA: Popliteal Angle, GCM - MT: Gastrocnemius Muscle Thickness, Avg: Average, SD: Standard deviation.*p<0.05*

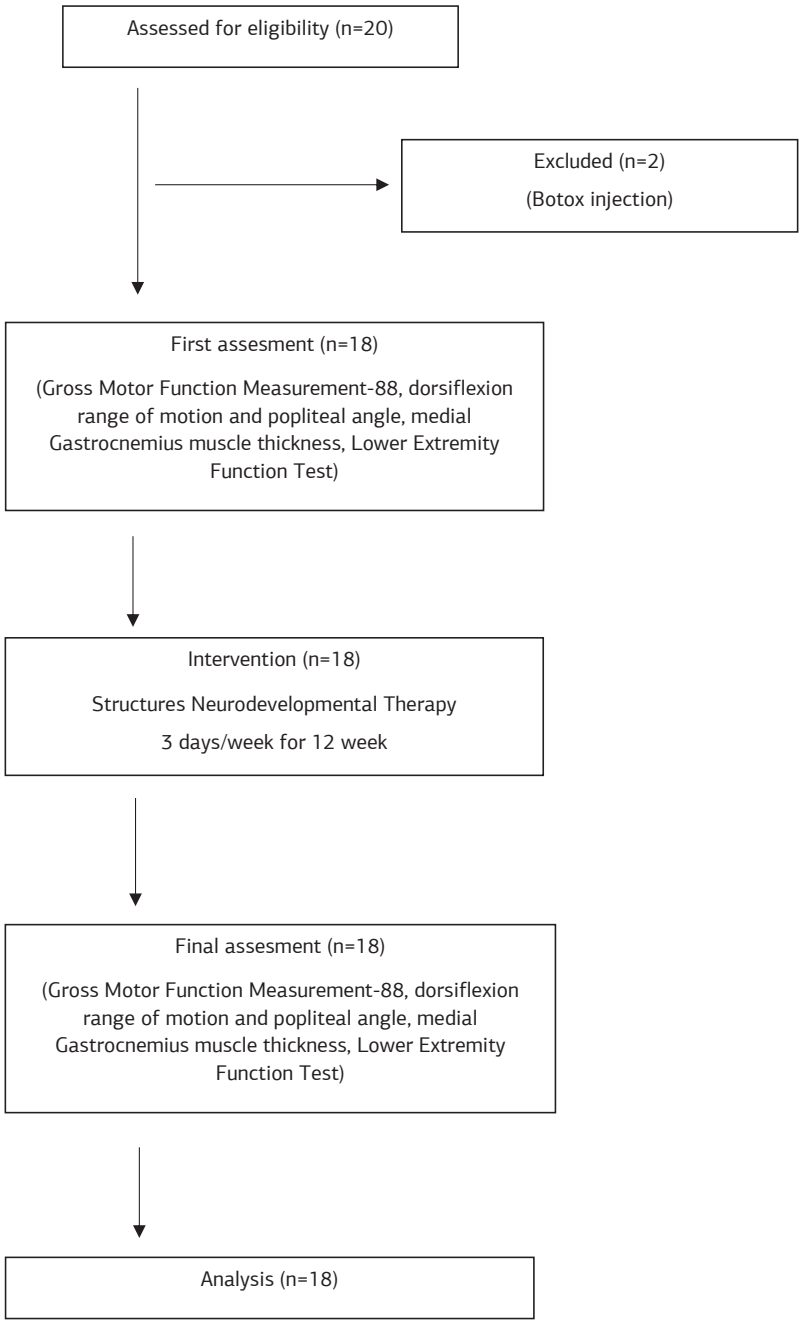

Figure 1: Flow chart of the study

Assessment values of motor function levels, ankle dorsiflexion ROM and popliteal angle, Muscle thickness values, and lower extremity functionality obtained before and after intervention were shown in Table 2. Statistically significant improvements were found in terms of GMFM-88 (p=0.001), Lower Extremity Function Test (p=0.000), ankle dorsiflexion ROM (p=0.002), and GCM muscle thickness (p=0.000). There was no statistically significant difference in popliteal angle (p=0.052).

DISCUSSION

The results supported the hypothesis, demonstrating that s-NDT contributes to children with hemiparetic CP improving the medial GCM MT, ankle dorsiflexion ROM, and functionality. The Bobath/NDT approach normalizes muscle tone, prevents primitive and abnormal reflexes, and facilitates normal movements. Bobath concept is continuously developing based on neuroplasticity and motor

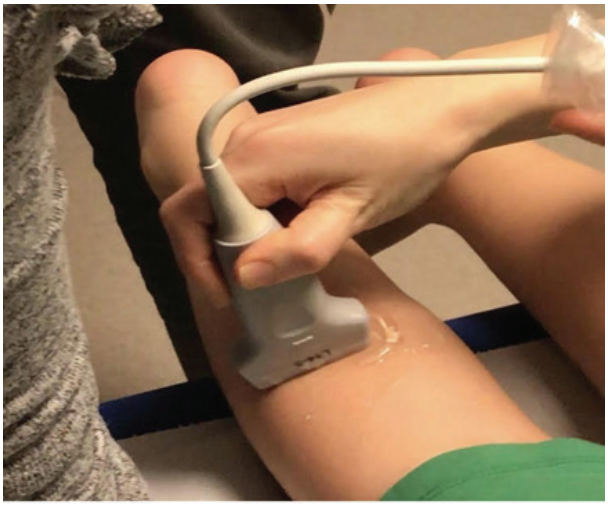

Figure 2: Ultrasonographic measurement of the gastrocnemius muscle.

It is critical to adopt physiotherapy approaches that optimize the child's potential by focusing on function and movement in CP rehabilitation. The importance of 2-8 weeks of strengthening exercises in healthy children to increase EMG activation by training nervous mechanisms and motor unit firings is emphasized (5, 7). Vercuren et al. emphasized that exercise training should be continued for at least 12 weeks to be effective in children with CP (17). A 12-week neurodevelopmental treatment program for children with hemiparetic CP was applied in this study.

The Gross Motor Function Scale (GMFM) and the GMFM-88 are functional assessment tools commonly used as primary outcome measurements in studies evaluating the effectiveness of NDT on motor function in children with CP (13). GMFM-88, the gold standard, is an observational assessment scale developed to evaluate gross motor function in children with CP. It is widely used to evaluate motor function in children with CP aged five months to 16 years (13). Van den Broeck et al. (18) evaluated the effectiveness of an individually defined 6-week physiotherapy program on functionality and gait patterns in 16 children aged 3-12 years with GMFCS I-II level. They reported that GMFM-88 significantly improved walking, running, and jumping movements. Knox et al. (19) observed a significant increase in the GMFM-88 total score at 6-week intervals (baseline, before and after Bobath treatment, and follow-up) of the functional benefits of Bobath treatment in 15 children with CP. In this study, a 12-week s-NDT program was applied in children with hemiparetic CP, and our results indicated that a 12-week s-NDT program provides significant improvements in GMFM-88 (walking, climbing, running mode) scores in children with diparetic CP.

Hemiparetic children can usually walk independently between 18-24 months. Children with hemiparetic CP who gain the ability to walk at an early age need to reduce their energy consumption while walking, improve their walking quality and boost their level of participation in life. Foot deformities are seen in approximately 70-90% of children with CP (20,21). The severity of foot deformity can have important effects on the overall walking ability of children with CP. McDowell et al. (22) reported that the ankle dorsiflexion angle was 3.7° while in the knee extension position in 50 hemiparetic CP children aged between 4-10. In this study, we found the ankle dorsiflexion angle value in the knee extension position was 4.33°, similar to this study. An increasing popliteal angle value is typically interpreted in clinical practice to suggest decreased hamstring length, tightness, or contracture, indicating changes in mechanical properties. In our study, there was a significant difference in ankle dorsiflexion ROM, and we found that the change in popliteal angle was not significant. While popliteal angle values were observed as 30-40 degrees in children with CP above in the literature, in our study, the mean popliteal angle value was 19.88. We think this result is related to the fact that most of the children in the study group (n=11) were at the GMFM I level and had a lower average age than the literature sample (23). It has been shown that changes in the pelvis and hip joint affect all joints in CP, including the ankle (24).

We propose that with the Bobath principle-based treatment, the ankle ROM angles improved as the child's proximal body awareness and pelvic control improved. Muscle weakness and motor disorder in children with spastic CP are linked to their functionality, and skeletal muscle architecture can significantly influence their muscle functions. Ultrasonography is the most objective and useful tool for determining muscle size changes related to muscular strength and function (11).

GCM is critical for maintaining anti-gravity posture in the standing position, the pushing phase of walking, and the most efficient energy consumption throughout walking (25). Rose and McGill (26) emphasized that the GCM lost 50% strength, and the motor unit activation rate was lower in children with CP during the walking push phase than healthy controls. They also stated that children with CP cannot activate the high-threshold motor unit groups required for maximum voluntary contraction, and those low-threshold motor units cannot change the firing speed. Barret et al. In a systematic study examining muscle morphology in children with spastic CP, it was emphasized that there was a significant difference between paretic and typically developing muscle thicknesses and that TCM muscle thickness was less in children with CP compared to their peers (27). Lee et al. applied 18 sessions of NDT to a group of 13 patients for six weeks and reported a non-significant increase in the thickness of the GCM muscle (12). Furthermore, researchers found that progressive functional training improved the pennation angle of GCM substantially, and they suggested that functional training be combined with conventional therapies. Improvements in GCM thickness were shown to be statistically significant in this study. We believe that variations in the substance and duration of the treatments utilized may have resulted in varied outcomes.

Although the increase in muscle thickness caused by the rise in adipose tissue in muscle tissue may not always support the gain in strength in children with cerebral palsy, our hypothesis was in this direction. We also examined their functionality because we didn't think isolated muscle strength assessment was appropriate in our cases, and we believe that improving functionality also enhances muscular strength.

Hemiparetic children's functionality is impaired by asymmetry, increased tone, loss of muscle strength, and sensory problems. Although the lower extremity function test is a commonly used functional test in the literature in children with idiopathic toe walking and musculoskeletal injuries, no study investigating the validity and reliability of the lower extremity function test in children with CP has been published to our knowledge. (28). After 12 weeks of s-NDT treatment, we observed significant improvements in LEFT scores in our study. We believe that the substantial gain in lower extremity function tests is attributable to the treatment program's positive impression of balance-based structured neurodevelopmental therapy.

The limitations of this study were that the LEFT test was not previously used in children with cerebral palsy who were GMFCS 1 and 2 levels, children with a wide age range were included in the study, age-related changes in motor function, and short treatment duration. The strengths of our study are to evaluate the effectiveness of NDT with objective (muscle ultrasound) and functional measurement (GMFM-88 and LEFT) criteria and include only children with hemiparetic type CP.

We recommend that more studies be done using various rehabilitation methods with a large sample size and a control group.

In conclusion, s-NDT was found to be effective in improving motor function, ankle dorsiflexion, medial GCM MT, and lower extremity functionality in children with hemiparetic CP in this pilot study. These enhancements will have a substantial positive impact on children's mobility.

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Conflict of Interest: The authors report no conflict of interest

Ethical Approval: Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee approved the study. (Approval Date: 27.12.2019 and Approval Number 10840098-604.01.01-E.66352)

Informed Consent: Written informed consent was obtained from all the study participants' parents or legal guardians.

Peer-Review: Externally peer-review

Author contributions: U.A. and D.T. designed the study and wrote the manuscript. U.A. collected and analyzed data. All authors read and approved the final manuscript.

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