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EFFECTS OF INDIVIDUALLY STRUCTURED TRUNK TRAINING ON BODY FUNCTION AND STRUCTURES IN CHILDREN WITH SPASTIC CEREBRAL PALSY: A STRATIFIED RANDOMIZED CONTROLLED TRIAL

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ORIGINAL ARTICLE

ABSTRACT

Purpose: This study aimed to investigate the effects of trunk training on body function and structures of children with spastic cerebral palsy (CP).

Methods: Children included in this study were classified according to the Gross Motor Function Classification System (GMFCS) and divided into two groups by stratified randomization based on their GMFCS levels and ages. A total of 36 children with bilateral spastic CP were recruited for this study, and 19 children (4 females, 15 males, age=8.81±3.92 years) were included in the trunk training group, and 17 children (6 females, 11 males, age=10.44±4.63 years) were included in the control group. Muscle tone of upper and lower extremity muscles was assessed using the Modified Tardieu Scale (MTS), and muscle activation of the trunk muscles was assessed using Surface Electromyography during rest (sEMG minimum) and forward reaching (sEMG maximum) at baseline and after an eight-week intervention.

Results: When the therapy-induced changes were considered, it was seen that there was no difference in muscle tone in both groups (p>0.05). The sEMG maximum scores for erector spinae muscles (p=0.025 for right and p=0.006 for left) improved in the trunk training group. There was no change in the sEMG scores of lumbar multifidus, M. rectus abdominis, internal oblique-transversus abdominis, external oblique, and M. gluteus maximus muscles (p>0.05).

Conclusion: Individually-structured trunk training is a promising method to increase activation of trunk extensors. This intervention can be used safely without the risk of increasing muscle tone of upper and lower extremities in children with CP.

Key Words: Cerebral Palsy; Child, Exercise; Muscles; Rehabilitation.

SPASTİK SEREBRAL PALSİLİ ÇOCUKLARDA BİREYSEL YAPILANDIRILMIŞ GÖVDE EĞİTİMİNİN VÜCUT YAPI VE FONKSİYONU ÜZERİNE ETKİSİ: TABAKALANDIRILMIŞ RANDOMİZE KONTROLLÜ ÇALIŞMA

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Bu çalışmanın amacı, spastik serebral palsili (SP) çocuklarda gövde eğitiminin; vücut yapıları ve fonksiyonları üzerindeki etkilerini araştırmaktı.

Yöntem: Bu çalışmaya dahil edilen çocuklar Kaba Motor Fonksiyon Sınıflandırma Sistemi'ne (KMFSS) göre sınıflandırıldı; yaşlarına ve KMFSS seviyelerine göre tabakalı randomizasyon ile iki gruba ayrıldı. Gövde eğitimi grubuna 19 çocuk (4 kız, 15 erkek, yaş=8,81±3,92 yıl), kontrol grubuna 17 çocuk (6 kız, 11 erkek, yaş=10,44±4,63 yıl) olmak üzere toplam 36 bilateral spastik SP tanılı çocuk dahil edildi. Üst ve alt ekstremite kaslarının kas tonusu Modifiye Tardieu Ölçeği (MTÖ) ile, gövde kaslarının kas aktivasyonu yüzey elektromiyografi ile dinlenme (sEMG minimum) ve ileri doğru uzanma aktivitesi (sEMG maksimum) sırasında değerlendirildi. Değerlendirmeler başlangıçta ve sekiz hafta süren müdahaleden sonra yapıldı.

Sonuçlar: Tedavinin etkisi ile meydana gelen değişimler incelendiğinde, her iki grupta da kas tonusunda herhangi bir değişim olmadığı görüldü (p>0,05). Erektör spina kasları sEMG maksimum skorları gövde eğitimi grubunda iyileşme gösterdi (sağ için p=0,025 ve sol için p=0,006). Lumbal multifidus, M. rectus abdominis, internal oblik-transversus abdominis, eksternal oblik ve M. gluteus maximus kaslarının sEMG değerlerinde herhangi bir değişim yoktu (p>0.05).

Tartışma: Bireysel yapılandırılmış gövde eğitimi gövde ekstansör kaslarının aktivasyonunu artırmak için umut verici bir yöntemdir. Bu müdahale, SP'li çocuklarda üst ve alt ekstremitelerde kas tonusunda artış riski olmaksızın güvenle kullanılabilir.

Anahtar Kelimeler: Serebral Palsi; Çocuk; Egzersiz; Kaslar; Rehabilitasyon.

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INTRODUCTION

A considerable amount of definitions of cerebral palsy (CP) can be found in the literature. "International Working Group on Definition and Classification of Cerebral Palsy" defines CP as a group of permanent disorders of the movement and posture development causing activity limitation as a result of non-progressive disturbances that develop in the immature brain (1).

Nearly half of the children with CP needs assistance to stand or walk because they have difficulty in achieving their postural alignment and stability against gravity (1). They also have difficulty in maintaining a stable sitting position, and they generally sit in an asymmetric position with increased kyphosis (2). The trunk is the center of the body and has an essential role in postural control and balance reactions (3). Coordinated activation of flexors and extensors of the trunk and hip is necessary for maintaining a balanced sitting position. Trunk control and active participation of trunk muscles are necessary to ensure a stable support surface during upper and lower extremity functions, including reaching and walking (4,5). However, insufficient control of trunk muscles leads to compensation of extremity muscles to maintain an upright posture. Impaired upper extremity kinematics during reaching is related with abnormal trunk movements, including excessive anterior positioning of the trunk.

Despite trunk involvement is one of the main factors affecting motor skills of children with CP, it seems that this issue has not been investigated in the literature adequately. Many studies are assessing the effects of hippotherapy/therapeutic horseback riding, electrotherapy and kinesiological taping on trunk control (2,6-9) in children with CP. However, a small number of studies was concerned with trunk training directly, and they concluded that the inclusion of exercises aiming the trunk in conventional physiotherapy affected motor function positively (10,11). However, exercises in these studies were not individually structured.

The effects of trunk training can be assessed using various methods, including manual muscle testing. However, it has been concluded that muscle strength cannot be assessed precisely with standard manual muscle testing or performance tests in children with CP. Problems such as insufficient motor control and increased co-activation of antagonistic muscles especially can decrease the force production capacity of agonistic muscles. Furthermore, muscle shortness and contractures restrain standard testing positions, and therefore, modifications should be made during testing (12). Assessments performed using isometric and isokinetic dynamometers at slow velocities have been found as reliable but, motor control problems may hinder manual muscle tests and the tests that use dynamometers in children with severe motor involvement (13,14).

Surface Electromyography (sEMG), which does not assess muscle strength directly yet it is an objective method of giving information about muscle activation patterns. Muscle activation of the trunk muscles was assessed using sEMG at rest (sEMG minimum) and during forward reaching (sEMG maximum). Forward reaching activity rather than specific activities for specific muscles is preferred because it is a functional activity that children use in their daily life and is easy to understand (9,12).

The importance of trunk control, and the necessity and the difficulty of determination of the effects of trunk training are mentioned above in details. In line with these requirements, the purpose of this study was to investigate the effect of individually structured trunk training on body functions and structures of children with bilateral spastic CP.

METHODS

Participants

Children between the ages of 4 years and 18 years, who had bilateral involvement and were diagnosed as spastic CP by pediatric neurologists, who understood and followed verbal instructions and whose family accepted to participate, were included in this study. Children, who had orthopedic surgery or received Botulinum Toxin A (BoNT-A) injection during the last six months or had seizures in the past year, were excluded.

Study Design

Participants joined the study between January 2014 and October 2015. Design of the study was stratified randomized controlled trial. Hacettepe

University Ethics Committee approval was obtained for this study (Number: GO 14/135). Children included in this study had received a consultation for a physiotherapy program and were enrolled in a physiotherapy program in a specialized education center in Bolu and Düzce cities, or their parents attended Department of Physical Therapy and Rehabilitation, Abant İzzet Baysal University. Parents of the children were informed about the interventions and benefits of the study and written informed consents of them were received. Some of the children recruited for this study lived at government's care centers for disabled children. Permission of the concerned ministry was received for those children.

G*Power (Version 3.1, Dusseldorf, Germany) power analysis program was used to determine the sample size. The parameters were set as $\alpha=0.05$, $1-\beta=0.95$ and effect size=0.25, and the number of cases to be included in the study was found to be 36 in total for the two groups. Children were divided into two groups according to their ages and Gross Motor Function Classification System (GMFCS) levels by stratified random sampling. The XLSTAT (XLSTAT, Addinsoft, Paris, France) data analysis software was used to perform stratified randomization. Participants were recorded in the system and divided into two groups by using the software. This study has been registered at ClinicalTrials.gov with the title of "Analyzing the Effect of Trunk Training on Limbs in Children with Spastic Cerebral Palsy" and the number is ID NCT02643160.

Intervention

Trunk Training Group

Exercises and activities focusing on activation of the trunk muscles, pelvic control, and proximal stabilization, combined with trunk and gluteal muscle strengthening exercises, were used in children who were included in the trunk training group (TTG) according to the neuro-developmental treatment (NDT) principles (15). These exercises can be summarized as follows: tone-influencing patterns, reaching activities with trunk elongation (in different sitting positions and different surfaces), selective pelvic movements, facilitation of spinal extension in prone position by using hands on/hands off techniques at different key points (on therapy mat, ball, roll, etc.), facilitation of spinal extension in sitting position by using hands-on/handoff techniques at different key points (in different sitting positions and different surfaces), facilitation of trunk flexion in supine position by using hands on/hand off techniques at different key points (on therapy mat, ball, roll, etc.), weight shifting and weight-bearing activities on pelvis (in different sitting positions and different surfaces), bridging exercises with extended knees (with ball, roll, etc.), unilateral hip abduction in bridge position, hip abduction in side lying, hip extension in prone position, crunches, lateral crunches, oblique crunches, and lower abdominal strengthening exercises. Exercises were performed as active assistive, active or manually resisted based on the child's capacity.

Tone-influencing patterns were used as preparation at the beginning of the session, and they were repeated when needed. Other exercises were performed as 30 repetitions; however, when the quality of the movement was worsened during the performance, a small break (1-3 minutes) was taken, and then the next exercise was continued. At the trunk training sessions; a parent or caretaker of the child had to be present in the therapy room, and had to watch the exercises and motivate the child during exercises. Poor postures were determined, and habits leading to those postures were questioned for all children, and specific recommendations were given according to their condition to maintain a good posture at school, home or any environment during the day.

Children in the TTG had received 45 to 75 minutes of physiotherapy twice a week during eight weeks in addition to their regular physiotherapy (twice a week for 45 minutes at a specialized education center). Exercises were individually structured according to gross motor function levels, performances, cognitive abilities, and fatigue levels of the children.

Control Group

Children who were recruited for the control group (CG) were asked to continue their routine physiotherapy (for 45 minutes, twice a week during eight weeks at a specialized education center). Physiotherapy programs of the children in the control group were carried out by a physiotherapist at a specialized education center. The content of the therapy programs was questioned, and it was made sure that none of the children had received individually-structured interventions focusing on the trunk.

Outcome Measurements

Information on the age, height, weight, gender, the method of delivery, birth week, birth weight, topographic distribution, and oral medications were recorded for all of the participants.

Muscle Activation: Surface Electromyography

In this study, sEMG was performed based on recommendations of Surface EMG for the Non-Invasive Assessment of Muscles Project (Seniam Project). The skin was shaved in case there was hair and was cleaned with alcohol or wet wipes before electrode placement. First, electrodes were attached to the wires of Myomed 932 sEMG Biofeedback device (Enraf-Nonius International, Rotterdam, The Netherlands) and then they were placed on the targeted muscles to avoid uncomfortable manual pressure. Electrode placement was performed according to Seniam Project for lumbal multifidus and erector spinae muscles and M. gluteus maximus muscle (16-18) and literature review for M. rectus abdominis, internal oblique-transversus abdominis, external oblique muscles (18-20). Additional information about electrode placement is provided in Appendix

Table 1: Characteristic of the Children.

Variables		**TTG (n=19)**	**CG (n=17)**	**p**
		Mean±SD	**Mean±SD**	
Age (years)		8.81±3.92	10.44±4.63	0.377$^{\phi}$
Height (cm)		121.12±19.85	131.25±26.61	0.273$^{\phi}$
Weight (kg)		26.18±12.66	35.42±19.70	0.438$^{\phi}$
		n (%)	**n (%)**	
Gender	**Girl**	4 (21.05)	6 (35.29)	0.351$^{\delta}$
	Boy	15 (78.95)	11 (64.71)	
Topographic Distribution	**Diparetic**	10 (52.63)	11 (35.29)	0.463$^{\delta}$
	Quadriparetic	9 (47.37)	6 (64.71)	
Birth Week	**<37 weeks**	11 (57.89)	10 (58.82)	0.878$^{\delta}$
	37-40 weeks	8 (42.11)	7 (41.18)	
Method of Delivery	**Natural**	4 (21.05)	8 (47.05)	0.218$^{\delta}$
	Cesarean	15 (78.95)	9 (52.95)	
Birth Weight (gr)	**<1500 gr**	8 (42.10)	9 (52.94)	0.866$^{\delta}$
	>1500 gr	11 (57.90)	8 (47.06)	
Use of Oral Myorelaxant	**Yes**	12 (63.15)	12 (70.58)	0.632$^{\delta}$
	No	7 (36.85)	5 (29.42)	
GMFCS Levels	**Level I**	6 (31.57)	8 (47.05)	0.478$^{\phi}$
	Level II	4 (21.06)	3 (17.65)	
	Level III	2 (10.52)	1 (5.88)	
	Level IV	4 (21.06)	3 (17.65)	
	Level V	3 (15.79)	2 (11.77)	

$^{\phi}$Mann Whitney u test; $^{\delta}$Chi-square test. GMFCS: Gross Motor Function Classification System; TTG: Trunk Training Group; CG: Control Group.

Table 2: Baseline Surface Electromyography and Modified Tardieu Scale Values of Trunk Training Group and Control Group.

Variables		TTG (n=19)	CG (n=17)	p
		Mean±SD	Mean±SD	
sEMG-Minimum Values				
Lumbal Multifidius	**Right**	3.17±5.94	1.67±2.32	0.436
	Left	3.17±5.97	2.13±2.64	0.779
Erector Spinae	**Right**	7.28±9.63	3.67±5.20	0.187
	Left	5.28±8.95	5.47±8.63	0.700
Rectus Abdominis	**Right**	2.78±3.43	2.27±2.21	0.783
	Left	3.89±4.89	1.60±1.80	0.106
Internal Oblique/TransversusAbdominis	**Right**	3.44±4.93	1.33±1.63	0.148
	Left	2.61±3.69	0.80±1.14	0.079
External Oblique	**Right**	2.72±3.00	1.73±1.58	0.303
	Left	2.56±2.43	1.80±1.85	0.351
Gluteus Maximus	**Right**	1.61±2.20	0.07±0.25	**0.001***
	Left	4.17±9.64	0.00±0.00	**0.004***
sEMG-Maximum Values				
Lumbar Multifidius	**Right**	45.94±31.40	65.93±63.37	0.448
	Left	82.44±118.60	63.07±41.06	0.704
Erector Spinae	**Right**	63.78±26.39	87.33±43.57	0.143
	Left	73.56±44.29	94.67±50.70	0.199
M. Rectus Abdominis	**Right**	36.89±49.56	27.80±13.84	0.691
	Left	34.44±19.50	35.40±38.99	0.469
Internal Oblique/Transversus Abdominis	**Right**	23.89±16.94	26.67±30.43	0.786
	Left	28.22±24.10	41.60±93.32	0.319
External Oblique	**Right**	39.78±32.13	43.47±36.60	0.899
	Left	32.50±14.20	64.40±56.41	0.071
M. Gluteus Maximus	**Right**	18.00±16.16	30.33±46.53	0.664
	Left	23.89±30.40	32.40±94.05	0.799
MTS R2-R1				
Shoulder Adductors	**Right**	6.50±21.58	8.06±24.66	0.869
	Left	12.50±31.49	5.33±13.16	0.697
Shoulder Internal Rotators	**Right**	9.50±17.00	7.78±19.86	0.571
	Left	11.00±18.89	4.11±8.71	0.385
Elbow Flexors	**Right**	21.40±35.08	8.44±25.18	0.112
	Left	33.35±41.99	11.67±34.34	**0.028***
Forearm Pronators	**Right**	7.25±18.02	5.56±16.88	0.795
	Left	8.85±16.76	3.44±11.95	0.270
Wrist Flexors	**Right**	5.50±10.50	5.56±16.88	0.538
	Left	10.50±19.59	1.67±5.14	0.065
Finger Flexors	**Right**	10.00±22.00	4.44±16.52	0.270
	Left	7.00±17.52	3.89±16.49	0.128
Hip Adductors	**Right**	7.00±7.14	7.89±8.27	0.775
	Left	8.10±8.82	10.17±10.22	0.518
Hamstrings	**Right**	11.85±10.14	9.00±8.57	0.436
	Left	9.45±10.89	7.00±7.36	0.702
M. Gastrocnemius	**Right**	19.00±10.77	17.78±7.32	0.780
	Left	16.95±10.62	17.11±9.43	0.626
M. Soleus	**Right**	20.30±9.75	16.72±10.19	0.227
	Left	16.40±13.12	17.89±8.69	0.454

*p<0.05. TTG: Trunk Training Group; CG: Control Group; sEMG: Surface Electromyography; MTS R2 R1: Modified Tardieu Scale Spasticity Degree.

I. Data were collected in sitting position during rest (minimum values, microvolt µv) and during forward reaching (maximum values, microvolt µv) using sEMG biofeedback device. The EMG work-rest, pair channel mode of the device was used. Sensitivity was set at 1000 µv, and the threshold value was set at 0 µv, and the filter was set as average. During sEMG assessment, children sat in a chair with back support that allowed foot contact with the ground and 90 degrees of knee and hip flexion. The forearm of each child was measured. An object was positioned on the wall at eye level and at forearm distance. Children were asked to sit as resting with their arms on their lap and then they were asked to reach to the object with both hands upon the "reach" command. The "reach" command was repeated in 5 seconds to make sure that maximal muscle contraction was obtained and maintained. After 5 seconds of forward reaching, children were asked to relax. Each child was applied a practice session, and in case they were successful in the test, the assessment was commenced.

Modified Tardieu Scale

The Modified Tardieu Scale (MTS) is a clinical scale to assess spasticity by grading resistance to passive movement. Assessments were performed in supine position and other parts of the body, especially the head position, must be stable during the assessment. Muscle reaction angle (Y) consisting of goniometric assessment was performed at two velocities. The V1 (as slow as possible and slower

Table 3: Comparison of Changes in Outcomes from Baseline to Eight Weeks in the Trunk Training Group and the Control Group for Surface Electromyography Values.

Surface Electromyography		**TTG (n=19)**	**CG (n=17)**	**p**
Minimum Values		**Mean±SD**	**Mean±SD**	
Lumbar Multifidius	**Right**	-0.64±7.55	-0.68±1.30	0.420
	Left	-0.70±6.74	-1.06±1.83	0.389
Erector Spinae	**Right**	-3.82±9.10	-0.60±4.25	0.251
	Left	-1.35±10.23	-1.53±4.65	0.480
M. Rectus Abdominis	**Right**	-0.64±4.10	-0.11±1.69	0.058
	Left	-2.76±4.95	0.06±1.79	**0.030***
Internal Oblique/Transversus Abdominis	**Right**	-2.23±4.73	-0.33±0.81	0.190
	Left	-1.17±2.96	-0.20±1.20	0.500
External Oblique	**Right**	0.76±2.70	-0.43±1.31	0.553
	Left	-0.64±2.42	-0.31±1.92	0.711
M. Gluteus Maximus	**Right**	1.61±2.20	0.07±0.25	**0.001***
	Left	4.17±9.64	0.00±0.00	**0.004***
Maximum Values				
Lumbar Multifidius	**Right**	19.70±34.14	4.20±97.84	0.227
	Left	22.64±85.25	16.06±83.42	0.428
Erector Spinae	**Right**	14.52±29.57	-7.13±32.40	**0.025***
	Left	13.17±32.98	-21.26±32.84	**0.006***
M. Rectus Abdominis	**Right**	-9.17±49.33	-1.53±16.15	0.623
	Left	1.17±22.96	-6.06±31.44	0.734
Internal Oblique/Transversus Abdominis	**Right**	8.05±27.46	-0.86±20.07	0.484
	Left	12.29±55.88	-16.73±89.66	0.265
External Oblique	**Right**	3.05±59.19	9.00±49.69	0.335
	Left	5.41±35.84	0.40±72.87	0.910
M. Gluteus Maximus	**Right**	18.0±16.16	30.33±46.53	0.664
	Left	23.89±30.40	32.40±94.05	0.799

*p<0.05. TTG: Trunk Training Group; CG: Control Group.

Table 4: Comparison of Changes in Outcomes from Baseline to Eight Weeks in the Trunk Training Group and the Control Group for Modified Tardieu Scale.

Modified Tardieu Scale R2-R1		TTG (n=19) Mean± SD	CG (n=17) Mean± SD	p
Shoulder Adductors	Right	7.26±23.76	1.47±11.14	0.663
	Left	2.10±11.51	1.70±10.69	0.748
Shoulder Internal Rotators	Right	-0.63±11.29	-1.76±13.80	0.630
	Left	-4.21±13.48	4.00±9.72	0.080
Elbow Flexors	Right	-2.42±17.60	3.41±10.71	0.229
	Left	-9.63±29.35	-3.29±22.51	0.571
Forearm Pronators	Right	-2.89±17.59	-3.05±17.58	0.931
	Left	-1.15±16.51	-1.88±10.13	0.739
Wrist Flexors	Right	-0.10±7.61	-0.11±2.86	0.731
	Left	-1.36±14.98	-1.05±4.90	0.281
Finger Flexors	Right	-6.84±24.73	-1.76±5.28	0.663
	Left	3.68±21.91	-1.76±7.27	0.654
Hip Adductors	Right	-0.84±9.56	0.82±7.04	0.301
	Left	-1.84±8.92	0.35±7.77	0.821
Hamstrings	Right	-1.63±10.03	1.17±14.83	0.631
	Left	2.36±10.76	0.00±11.81	0.327
M. Gastrocnemius	Right	-0.21±14.00	-1.41±9.29	1.000
	Left	1.10±8.33	-2.58±7.47	0.192
M. Soleus	Right	0.94±8.31	0.76±9.36	0.911
	Left	2.05±10.09	1.35±8.75	0.886

TTG: Trunk Training Group, CG: Control Group; MTS: Modified Tardieu Scale; R2-R1: Modified Tardieu Scale Spasticity Degree.

than the natural drop of the limb segment under gravity) was used to assess the static component, and V3 (as fast as possible and faster than the rate of the natural drop of the limb segment under gravity) was used to assess the dynamic component. Bony landmarks were determined for the standardization of the goniometric measurements, and standard goniometry was used. Muscles were assessed first at V1 velocity and subsequently at V3 velocity. The Y parameter of V1 velocity was presented as R2, and Y parameter of V3 velocity was presented as R1. R2-R1 values gave the degree of spasticity (21-23). In this study, we calculated R2-R1 values for shoulder adductors and shoulder internally rotators, elbow flexors, forearm pronators, wrist flexors and finger flexors in the upper extremity, and hip adductors, hamstrings, gastrocnemius, and soleus muscles in the lower extremity. Testing positions are provided in Appendix II.

Assessment of the children performed and exercises of TTG were performed in the pediatric rehabilitation unit of Abant İzzet Baysal University by a physiotherapist, who had a nine-year pediatric rehabilitation experience.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) (PASW 18, SPSS Inc, Chicago, USA) was used for statistical analyses. Descriptive analyses were presented as means and standard deviations for continuous variables and in numbers and percentages for categorical variables (gender, topographic distribution). The differences in demographic characteristics between the groups were analyzed by using Chi-square test for categorical variables (gender, topographic distribution, delivery method, prematurity, birth weight classification) and Mann–Whitney U test was used for continuous variables (age, height, weight). The Wilcoxon Signed-rank Test was used to compare the differences between the baselines and post-intervention scores within the groups. Mann–Whitney U test was used to compare the differences between the groups. The level of significance was set at $p<0.05$.

RESULTS

We designated 65 children with CP to include in this study. Parents of the two children did not accept to join the study because of transportation problems, and they reported that it was complicated to travel with a child who was unable to walk. Sixteen children had severe cognitive impairments, two had unilateral Spastic CP, four had dyskinetic CP, three kept crying, and did not want to join the assessments or exercises, and therefore these children were not included. Overall 38 children with spastic CP, who accepted to join the study and were suitable according to the inclusion criteria, were included in this study.

One child from TTG had a seizure during the intervention period, and he did not develop seizure at the therapy session, however, since this condition was one of our exclusion criteria, this child was dropped from the study. One of the children from CG was dropped from the study because he had received a BoNT-A injection. The study was carried out with 36 children, 19 children (4 females, 15 males, mean age=8.81±3.92 years) were in TTG and 17 children (6 females, 11 males, mean age=10.44±4.63 years) were in CG. There was no difference between the groups regarding age, gender, topographic distribution, birth week, and birth weight. Demographic characteristics of the children and the distribution of the children in TTG and CG according to their GMFCS levels are shown in Table 1.

Baseline values of sEMG minimum for Gluteus Maximus muscle (right/left) were higher in TTG in comparison to the control group ($p<0.05$). There was no difference in baseline minimum and maximum sEMG values between the groups ($p>0.05$) for the other muscles. There were differences in MTS R2-R1 values of left elbow flexors between the groups ($p<0.05$) based on the baseline values and spasticity of these muscles were higher in TTG. There were no differences in the baseline values of MTS R2-R1 of other muscles between the groups ($p>0.05$). Baseline sEMG and MTS values of TTG and CG are shown in Table 2.

When the changes between the groups were analyzed, there was a decrease in M. rectus abdominis (left) and M. gluteus maximus (right/left) sEMG minimum values of TTG in comparison to CG ($p<0.05$). Moreover, there was an increase in Erector Spinae (right/left) sEMG maximum values of TTG in comparison to CG ($p<0.05$). When the changes that occurred following the treatment were analyzed, there was no difference in any of the muscles between-group comparisons for TTG or CG for MTS ($p>0.05$). The comparison of changes in the outcomes with eight week-intervention in the TTG and CG is shown in Table 3 and Table 4.

DISCUSSION

In this study, we analyzed the effects of trunk training on body functions and structures of children with spastic CP. We showed a decrease in M. rectus abdominis (left) and internal oblique/transversus abdominis (right/left) sEMG minimum values in TTG when compared with the baseline values. Moreover, the decrease of sEMG minimum values in TTG in M. rectus abdominis (left) and M. gluteus maximus (right/left) muscles was higher in CG. We did not have a control group of healthy children for comparison. However, we thought that sEMG activity at rest decreased since the children were able to maintain a stable sitting position and achieved better postural control. There was an increase in erector spinae (right/left) sEMG maximum values in TTG when compared with CG. It was a significant result for us because we performed many exercises to improve lumbar extension in TTG. There was no study reported in the literature as methodologically similar to our study. However, it has been shown in some studies that muscle activation can be changed with the NDT approach. Dos Santos et al. (24) have shown an increase in trunk extensor muscle activity by EMG during humeral external rotation facilitation (this technique is identical to the one that we used in our exercises in the prone position and during sitting). They have concluded that both internal rotation and external rotation facilitations increased trunk extensor activity, but the increase was higher with external rotation (24). However, there was no information provided about the content of the applied trunk control program in these studies. This situation makes it difficult to compare the results. Unger et al. (25) have reported improvement in the posture of children with CP as accompanied with full body vibration after a four-week trunk training. On the other hand, Curtis et al. (26) have reported that there was no difference in trunk control between children with CP who received segmental trunk control training and children who received routine physiotherapy.

Arı and Günel (11) applied Bobath therapy for trunk control in children with CP in addition to the classical physiotherapy programs, and they found improvement in trunk extensor strength as assessed by using manual muscle testing. The methodology (exercises used for trunk training, assessment methods, therapy duration, and frequency), which applied trunk training in these four studies mentioned above is different from our study substantially. This situation makes the comparison of the results and drawing a general conclusion about the effects of trunk training difficult.

Abnormal movement patterns can be observed in upper and lower extremities in children with CP during antigravity motor performances. Researchers have shown that insufficient trunk control worsens this condition, but it does not affect muscle tone (5,27). In this study, we assessed spasticity with MTS, a reliable technique to assess spasticity in children with CP (21,22). Muscle tone of upper and lower extremity muscles did not change with the intervention in TTG or CG. In contrast to our results, Arı and Günel (11) have reported a decrease in lower extremity muscle tone with a 6-week trunk control training. It has been reported in the literature that muscle strengthening exercises did not improve muscle tone. Fowler et al. (28) have reported that quadriceps strengthening exercises did not improve spasticity in children with CP. Lee et al. (29) have reported that there was an improvement in muscle strength with lower extremity closed kinetic chain exercises performed on an unstable ground and gait characteristics did not change in spasticity.

It was seen that the results of the measurements had high standard deviations because the children at all GMFCS levels were included in the study. We believe that the inclusion of an equal number of cases at each GMFCS level and making separate analyses of each level may be beneficial to determine the effects of the trunk training in children at different GMFCS levels in the future studies.

In conclusion, according to our study, trunk training based on NDT and muscle strengthening had positive effects on lumbar extensor muscle activation, and it can be used safely without the risk of increasing spasticity. Therapy programs of the children with CP must be individually structured based on children's capacity and needs.

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Conflict of Interest: The authors report no conflicts of interest.

Ethical Approval: The study was approved by the Ethics Committee of Non-interventional Clinical Research of Hacettepe University (GO 14/135).

Informed Consent: Written informed consent was obtained from all study participants.

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Appendix I: Electrode Placement Regions for Surface Electromyography.

1. Lumbar Multifidus	**Electrode Placement**	Aligned with the line from caudal tip posterior superior iliac spine to the interspace between L1 and L2 interspace at the level of L5 spinous process (i.e., about 2-3 cm from the midline).
	Reference Electrode	On the spinous process of C7.
2. Mm. Erector Spinae	**Electrode Placement**	Two finger width lateral from the spinous process of L1.
	Reference Electrode	On the spinous process of C7.
3. M. Rectus Abdominis	**Electrode Placement**	1 cm above the umbilicus, 2 cm lateral to the midline
	Reference Electrode	On the spinous process of C7, near wrist or ankle
4. M. Internal Oblique/ Transversus Abdominis	**Electrode Placement**	2 cm below, medial from the anterior superior iliac spine
	Reference Electrode	On the spinous process of C7, near wrist or ankle
5. External Oblique	**Electrode Placement**	Below the rib cage, oblique to the inferior costal angle
	Reference Electrode	On the spinous process of C7, near wrist or ankle
6. M. Gluteus Maximus	**Electrode Placement**	At the midpoint of the line between the sacral vertebra and the trochanter major (middle of the line between the SIPS and the gluteal fold).
	Reference Electrode	On the spinous process of C7, near wrist or ankle

Appendix II: Modified Tardieu Scale (Assessment Protocol for Muscle Reaction Angle).

Muscles	Reference Points for Goniometric Assessment		Movement
Shoulder Adductors: Arm positioned in rest on the assessment table, near to the body	**Axis**	Acromion	One hand placed on the humerus and the other hand on forearm. The shoulder has taken from a neutral position to full abduction.
	Stabilization Arm	Parallel to the sternum and columna vertebralis	
	Movement Arm	Anterior midline of the humerus	
Shoulder Internal Rotators: Arm positioned in 90 degrees of shoulder abduction and full internal rotation	**Axis**	Olecranon	One hand placed on the humerus and the other hand on forearm. The shoulder has taken from full internal rotation to full external rotation.
	Stabilization Arm	Parallel to the floor	
	Movement Arm	Between radius and ulna, parallel to the 3rd metacarpal bone	
Elbow Flexors: Arm positioned in rest on the assessment table with full elbow flexion	**Axis**	Lateral epicondyle of humerus	One hand placed on the humerus and the other hand on forearm. Elbow has taken from full flexion to full extension.
	Stabilization Arm	Lateral midline of humerus	
	Movement Arm	Proximal phalanx of the 3rd finger	
Forearm Pronators: Arm positioned in rest on the assessment table with 90 degrees elbow flexion and full forearm pronation, a pencil hold in hand	**Axis**	3rd metacarpophalangeal joint	One hand placed on the humerus and the other hand on forearm. Forearm has taken from full pronation to full supination
	Stabilization Arm	Parallel to the long axis of humerus or assessment table	
	Movement Arm	Parallel to the pencil	
Wrist Flexors: Arm positioned in rest on the assessment table, wrist flexed, hanged down from the lateral side of the assessment table	**Axis**	Styloid process of ulna	One hand placed on the forearm, the other hand on metacarpal bones. The wrist has taken from full flexion to full extension.
	Stabilization Arm:	Parallel to the ulna	
	Movement Arm	5th metacarpal bone	
Finger Flexors: Arm positioned in rest on the assessment table, with 90 degrees elbow flexion	**Axis**	5th metacarpophalangeal joint	One hand placed on metacarpal bones and the other hand on phalanxes. Fingers have taken from full flexion to full extension
	Stabilization Arm	Parallel to the 5th metacarpal bone	
	Movement Arm	Parallel to the 5th phalanx	
Hip Adductors: Hips positioned in the neutral position, knees in extension. Pelvis stabilized from the other side	**Axis**	Projection of trochanter major on anterior of the femur	One hand placed on the femur and the other hand on proximal to ankle. Hip joint has taken from full adduction to full abduction
	Stabilization Arm	Parallel to the line between two anterior superior iliac spine	
	Movement Arm	Anterior midline of the femur	
Hamstrings: Hips positioned in 90 degrees of flexion and knees in full flexion	**Axis**	Lateral condyle of the femur	One hand placed on the femur and the other hand on proximal to ankle. The knee joint has taken from full flexion to full extension
	Stabilization Arm	Lateral midline of the femur	
	Movement Arm	Lateral midline of the fibula	
M. Gastrocnemius: Hip positioned in rest and knee in extension	**Axis**	Lateral malleolus	One hand placed on proximal to ankle and the other hand on metatarsal bones. The ankle has taken from full plantar flexion to full dorsal flexion
	Stabilization Arm	Parallel to the lateral aspect of the fibula	
	Movement Arm	Midline of the 5th metatarsal bone	
M. Soleus: Hip and knee positioned in 45 degrees of flexion	**Axis**	Lateral malleolus	One hand placed on proximal to ankle and the other hand on metatarsal bones. The ankle has taken from full plantar flexion to full dorsal flexion
	Stabilization Arm	Parallel to the lateral aspect of the fibula	
	Movement Arm	Midline of the 5th metatarsal bone	

All the assessments made in the supine position, the child in rest, had in the midline, no pillow or a thin pillow can be used