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The effects of treadmill training on postural control and balance in children with spastic diplegic cerebral palsy: A cross-over controlled study

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Abstract

Background & Objective: Treadmill training (TT) is used for several targets as in walking speed and endurance in rehabilitation programs of children with cerebral palsy (CP). However, its effects on postural stability have not been fully explored. The aim of this study was to investigate the effects of unsupported TT on postural control (PC) parameters and balance in children with spastic diplegic CP. *Methods:* Twelve children with CP, level I-II according to Gross-Motor-Function-Classification-System (GMFCS) were included. Participants were divided into two groups using randomized-sampling method. The study was designed as a cross-over study. In the first phase, the first group underwent routine physiotherapy-rehabilitation program (PTR) 3 sessions/week, 45 minutes per session, for 12 weeks. In the second group, 20 minutes of TT starting with 0.5 km/h speed, was added to the same PTR (n=6). At the end of 12 week, 4-week-long wash-out period was given. After this 4 weeks period, both groups crossed-over for another 12 weeks at the second phase of therapy. All tests was applied at baseline and at end of the first and second phases. PC was evaluated with Balance-Master computerized posturography (Neurocom Inc.) which consisted of tests of modified-clinical-sensory-balance-interaction (MCSBT), weight-shifting-in-standing (WSST), limits-of-stability (LoST) and rhythmic-weight-shifting (RWST). *Results:* The two groups were similar in age, body composition, GMFCS Levels and spasticity levels before the treatment and after the wash-period ($p>0,05$). After TT, there were significant improvements in PC parameters, MCSBT: composite-balance-score ($p=0.02$), center of gravity alignment ($p=0.02$); WSST: symmetry ($p=0.03$); LoST: backward weight-shifting ($p=0,02$), end point reaching ($p=0.02$-0.04), maximum-orientation ($p=0.02$-0.04); RWST: direction-control ($p=0.02$-0.04), on-axis-velocity ($p=0.02$-0.04).
Conclusion: Including TT in PTR treatment program can enhance PC and balance in children with CP.

Keywords: Cerebral palsy, postural control, balance, rehabilitation

INTRODUCTION

Poor posture and movement restrictions are among the main problems of children with cerebral palsy (CP) and they exhibit poor postural control (PC) which is maintaining the body position in space through postural stabilization and orientation.[1,2] In CP, however, PC deficiency is primarily caused by the brain damage, leading to balance and/or orientation problems.[3]

Postural stability is essential in performing daily activities and requires the continuity of the vertical position of the body.[4,5] However in CP, sensory deficits, muscular weakness and biomechanical misalignment, impaired muscle activation, loss of selectivity in neuromuscular output and spasticity lead to problems with PC that adversely affect performance of daily activities.[6,7] This dysfunction provokes limitations in motor skills that require balance as in walking, and limits participation in a wide range of daily living including self-care, education, entertainment and social relationships.[8] Therefore, improvement of PC is one of the main goals in physiotherapy interventions.[6]

Spastic diplegia is a common type of CP where lower limbs are affected more than upper limbs. Children with diplegic CP (dCP) have difficulties in PC. They also experience difficulty with

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planning of motor responses, in relation to support surface perturbations as well as demonstrate deficiency in anticipatory postural adjustments while standing and walking.[9] Although children with dCP are reported to have better walking capacity, their poor PC puts them at higher risk of falling. This, indeed, leads to participation limitations and necessitates the inclusion of walking and PC trainings into clinical practices.[10] Contrary to the significant negative effects of PC dysfunction in children with CP, optimal intervention methods are poorly understood. Although there is a wide range of interventions aiming to improve movement and posture in children with CP, the effects of these interventions on PC have not been adequately investigated, and the effectiveness of most of these methods is controversial.[11]

The search for evidence for the effectiveness of physiotherapy and rehabilitation (PTR) in CP is an important subject, investigators have reported neurophysiological evidence of treadmill training (TT) in improving gait. In systematic reviews investigating the effectiveness of intervention methods for CP showed that TT for children with CP may be beneficial for walking speed, walking endurance, and gross motor functions, but emphasized that there was a need for more research about this subject, as few of the studies investigated effects of TT on PC objectively.[12-15]

TT provides multiple repetitions of stepping in rhythmic patterns in the gait cycle. Therefore, these rhythmic patterns can improve control of muscles, and lead to improvement in PC by increasing functional and static balance.[9] The aim of this study was to investigate the effects of unsupported TT on PC parameters and balance in children with spastic dCP.

METHODS

Study design

This was a cross over-controlled study. The evaluations were done at baseline, and at the end of 12th, 16th, and 28th weeks. The children and parents included in the study signed an informed consent. The study was approval by Hacettepe University Non-Interventional Clinical Researches Ethics committee (No: GO 16/368-41).

Participants

Twelve children aged between 6-15-year-old with spastic dCP who were Level I-II according to the Gross-Motor-Function-Classification-System (GMFCS) were included in the study. Children who had botulinum toxin injection in the last six months, undergone an orthopedic surgery in the past year, or visual impairment were excluded.

For determining gait characteristics, the children were classified according to Rodda and Graham, and classified as true equinus, jump gait, apparent equinus or crouch gait. True equinus was defined by the ankle in plantarflexion throughout stance phase and the hips and knees extended. Additionally, the equinus can be masked by a knee recurvatum. The jump gait pattern was characterized by equinus at the ankle, flexion at knee and hip, anterior tilt and increased lumbar lordosis. The apparent equinus pattern has a normal range of dorsiflexion at the ankle, but the hip and knee are in excessive flexion throughout the stance phase. Crouch gait was defined by excessive dorsiflexion at the ankle in combination with excessive flexion at the knee and hip joints.[16,17] Orthosis used by participants was recorded (Table 1).

Spasticity of lower limbs assessed with Modified Ashworth Scale (MAS). MAS was a 6-point rating scale which assesses muscle tone by manually manipulating the joint through its available range of motion and clinically recording the resistance to passive movements. Each participant was examined lying supine on a couch in a relaxed position. For standardization of stretching speed passive movements were made in one second as recommended by Bohannon and Smith.[18] The MAS is valid and reliable scale in children with spastic CP.[19] Gastrocnemius, soleus, hamstrings, hip adductor and flexor muscles were assessed bilaterally (Table 2).

The passive range of motion (ROM) of children with CP evaluated with universal goniometer. The positions used in this study were based on those of Stuberg *et al*. Ankle dorsiflexion, knee extension, hip extension and abduction were evaluated bilaterally. The degree of passive ROM recorded. The evaluation of ROM with universal goniometer is a reliable method in children with CP.[20]

Procedures

In line with the cross over-controlled study design, baseline evaluations of all participants were done at the beginning (1st evaluation). In the first stage, participants in Group A received 45 minutes of PTR program 3 times per week for 12 weeks, participants in Group B received 20 minutes of TT in addition to 45 minutes of PTR program 3

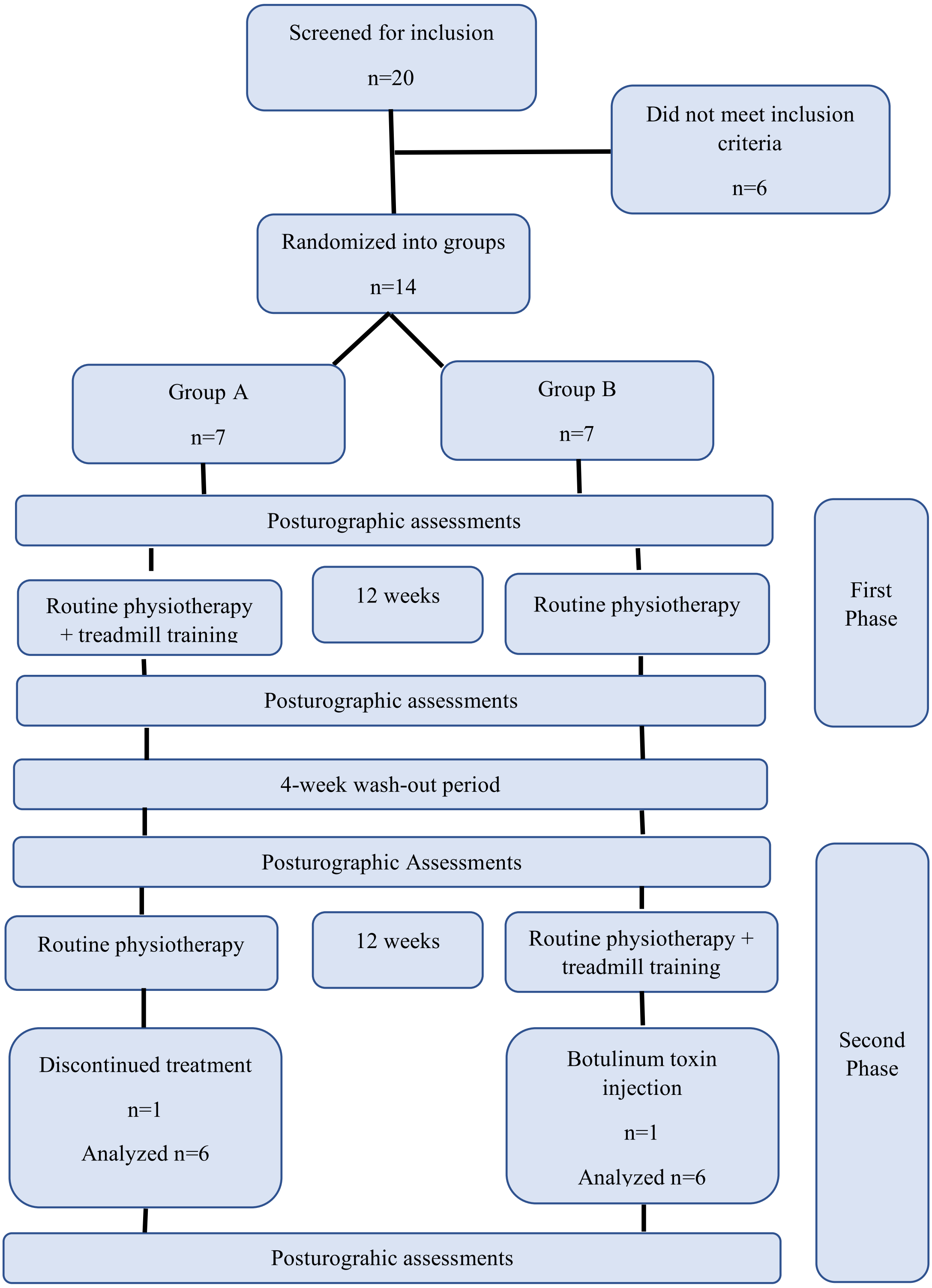

Figure 1. Flowchart of the study

Table 1: Clinical and demographic characteristics of the participants

Demographic feature	Group A (n=6)		Group B (n=6)		Z	p
	Mean (SD)		Mean (SD)			
Age (year)	9.66 (3.33)		10.16 (2.84)		-0.202	0.875
Body weight (kg)	32.16 (8.16)		36.16 (984)		-0.528	0.581
Height (cm)	135.16 (7.16)		137.3 (6.67)		-0.334	0.875
BMI (kg/m2)	17.56 (3.42)		19.18 (2.28)		-0.649	0.371
	n	%	n	%		
Gender						
Boy	5	83	4	66		
Girl	1	17	2	34		
GMFCS level						
I	4	66	3	50		
II	2	34	3	50		
Gait characteristics						
True equinus	2	34	1	17		
Jump gait	3	50	3	50		
Apparent equinus	1	17	2	34		
Crouch gait	-		-			
Type of orthosis						
Solid ankle foot orthosis	5	80	5	80		
Hinged ankle foot orthosis	1	20	1	20		

sessions per week for 12 weeks. At the end of the 12th week, both groups were re-evaluated (2nd evaluation) and there was a 4-week-long wash-period, after which all evaluations were repeated (3rd evaluation).

In the second stage of the study, treatment programs were crossed-over between the groups: At the end of the 12th week, all evaluations were repeated (4th evaluation) and the study was terminated.

Table 2: Spasticity assessments according to the Modified Ashworth Scale at Baseline

Muscles	Group A Left Mean (standard deviation)	Group B Left Mean (standard deviation)	Z	p
Gastrocnemius right	2.50 (0.57)	3.00 (0.81)	-0.949	0.486
Gastrocnemius left	2.00 (0.81)	3.50 (0.57)	-2.097	0.057
Soleus right	1.25 (0.50)	2.25 (0.95)	-1.559	0.200
Soleus left	1.50 (0.57)	2.50 (1.00)	-1.528	0.200
Hamstring right	2.50 (0.57)	3.25 (0.95)	-1.222	0.343
Hamstrings left	2.50 (0.57)	3.25 (0.50)	-1.667	0.200
Hip adductors right	2.25 (0.50)	3.00 (1.15)	-1.000	0.486
Hip adductors left	2.00 (0.81)	3.00 (1.15)	-1.239	0.434
Hip flexors right	2.00 (0.00)	2.00 (0.00)	0.00	1
Hip flexors left	1.75 (0.50)	2.50 (0.57)	-1.667	0.200

Intervention

According to the American Physical Therapy Association, the recommended treatment period and frequency of TT in children is 2-16 weeks and 2-5 sessions per week, respectively.[21] Nevertheless, another study concluded that 2-3 sessions per week for a total of 12 weeks would be appropriate to demonstrate the effectiveness of TT.[22] Accordingly, the treatment program of the present study was set as 3 times per week for 12 weeks.

Treadmill training: In addition to 45-minute-long physiotherapy program, children with their shoes on walked for 20 minutes on the treadmill (Dynamic Proform Power Plus N.) The velocity range was 0.5-0.8 km/h with an incline of 0% and applied as forward and backward walking. The initial speed was determined based on each patient's ability in maintaining full knee extension then was gradually increased in accordance with tolerance. Throughout the training, the position of trunk, hips and knees as well as posture were monitored and corrected by the physiotherapy with verbal and non-verbal cues, and initiation of swing, facilitation of heel contact, and attention to knee extension to facilitate the child walking.[15]

Routine PTR program: This program was based on gait training, muscle strengthening, trunk control exercises and balance exercises.[23]

Outcome measures

Posturographic evaluations were performed using the "Balance Master" posturography device (NeuroCom INC., Clackamas, Or, USA). None of the participants of the study had previously had a posturographic test. All the assessments were conducted by the same therapist (SA) who was blinded to the group allocation.

The following tests were applied:

Modified Clinical Sensory Balance Interaction Test (MCSBT): It provides objective evidence of sensory dysfunction. Postural sway rate is assessed in four sensory states: firm surface with the eyes open, firm surface with the eyes closed, unstable surface with the eyes open, and unstable surface with the eyes closed. The system uses a force plate that consists of two 9 × 18-inch foot plates, each of which rests on two force transducers with the sensitive axis orientated vertically. This allows assessment of the center of gravity for each patient as their height is entered into the computer. The computer then calculates the degrees of sway during each test. Each test lasts 10 seconds and is repeated three times and the degrees of sway are averaged. The foam dimensions match that of the force plate and rely on transmittance of sway pressures through the foam. The sway rate of the center of gravity (COG) is calculated for each test position; additionally, the composite score of the sway rate is also obtained. The composite score is obtained from averaging the four test conditions. While low sway rates indicate better clinical findings, higher rates indicate deterioration in balance-sensory-interaction. The alignment of the COG is also shown through the test.[24]

Weight Shifting in Standing Test (WSST): It evaluates the continuity of the equal weight shifting on each lower limb in upright position (0°) and in two different squat positions with 30° and 60° of knee flexion.[24]

Limits of Stability Test (LoST): It evaluates the maximum displacement of the individual's COG in four basic directions, front, back, right and left, and four diagonal directions, right-front, right-back, left-front and left-back, and assesses the continuity of stability in these positions. The test evaluates reaction time, displacement speed of theCOG, directional control, end point reaching, and maximum deviation.[24]

Rhythmic Weight Shifting Test (RWST): It evaluates the individual's ability to transfer the COG rhythmically in two directions, right-left and forward-backward, and in three different speeds. The parameters measured by the test are displacement speed of the COG along the axis and directional control.[24]

Statistical analysis

The IBM SPSS statistical software 26.0 was used. One-sample Kolmogorov–Smirnov tests were used to evaluate the distribution of normality. The washout effect was evaluated with the Wilcoxon Test between the first (pre-first program) and third (pre-second program) evaluations, and for changes of groups over time. The Mann-Whitney U Test was used to see the difference between therapies. The significance value was accepted as $p<0.05$. The sample size was calculated using the G*Power version 3.1.9.6 analysis program. To obtain 80% power and detect a difference with a 95% confidence interval using a two-tailed test, minimum 11 children with CP were required.

RESULTS

The mean age of the study groups (Group A, n=6; Group B, n=6) was 9.66±3.33 and 10.16±2.84 years, respectively. The groups were similar in terms of age, body weight, height, and body mass index. The demographic characteristics of the participants are presented in Table 1.

Outcome measures

MCSBT:

Among the parameters evaluated with the *MCSBT*, in TT, there was a statistically significant difference in composite score of sway rate and COG alignment between the evaluations of before and after the treatment. (respectively z=-2.220; -2.214 $p<0.05$). In routine physiotherapy group, there was not any statistically significant difference ($p>0.05$). (Table 2). When the effects of the two intervention approaches on *MCSBT* parameters were compared, it was found that TT was more effective on composite score of sway rate and COG alignment ($p<0.05$) (Table 3).

WSST

In standing positions, in TT group, there was

Table 3: Effects of treadmill training and routine physiotherapy

	Physiotherapy+Treadmill Training			**Routine Physiotherapy**		
	Pre Intervention mean (SD)	Post intervention mean (SD)	p	Pre Intervention mean (SD)	Post intervention mean (SD)	p
Modified Sensory Balance Interaction Test						
Composite score of sway rate	0.736 (0.18)	1.10 (0.33)	**0.02**	1.16 (0.34)	0.98 (0.2)	0.16
Center of gravity alignment	65 (21.77)	50 (16.07)	**0.02**	55.83 (16.5)	63.83 (3.12)	0.11
Weight Shifting in Standing Test						
0° Left	49.0 (7.66)	54.3 (3.82)	**0.03**	51.1 (3.37)	54.5 (7.58)	0.34
0° Right	51 (7,66)	45,6 (3,82)	**0.03**	48,8 (3,37)	45,5 (7,58)	0.34
30° Left	46.6 (8.04)	51.8 (2.63)	0.45	48.1 (7.67)	56.6 (9.91)	**0.04**
30° Right	53.3 (8.04)	48.1 (2.63)	0.45	51.8 (7.67)	43.3 (9.91)	**0.04**
60° Left	48.5 (11.2)	48.0 (5.58)	0.10	48.6 (5.88)	50 (3.28)	0.74
60° Right	51.5 (11.2)	52.0 (5.58)	0.10	51.3 (5.88)	50 (3.28)	0.74
Limits of Stability Clinical Test						
Reaction time composite	0.81 (0.08)	0.72 (0.18)	0.14	0.67 (0.55)	0.85 (0.26)	0.59
Reaction time backward	0,25 (0,27)	0,49 (0,44)	**0,02**	0,69 (0,60)	0,90 (0,79)	0,59
Movement speed	5.97 (1.36)	6.23 (2.08)	0.74	3.50 (2.86)	5.57 (1.79)	0.20
End-point reaching	36.00 (28.84)	68.50 (10.07)	**0.02**	67.00 (8.46)	75.17 (8.08)	0.11
Maximum orientation	78.33 (6.31)	89.67 (6.50)	**0.04**	50.17 (38.90)	79.50 (9.75)	0.75
Rhythmic Weight Shifting Test						
Right-left flow rate	5.98 (1.42)	6.21 (0.65)	0.34	5.01 (1.02)	5.91 (1.18)	0.11
Right-left direction control	66.3 (14.0)	73.10 (4.26)	**0.04**	75.80 (6.61)	74.50 (2.94)	0.91
Forward-backward flow rate	2.90 (1.26)	3.50 (0.45)	0.11	2.88 (0.34)	3.38 (0.54)	0.11
Forward-backward direction control	11.50 (12.90)	14.60 (19.20)	**0.02**	41.30 (22.7)	51.80 (12.50)	0.11

°: degree, SD: standard deviation

Table 4: Comparison of the effects of treadmill training and routine physiotherapy

	Physiotherapy+ Treadmill Training Δ mean (SD)	Routine Physiotherapy Δ mean (SD)	p
Modified Sensory Balance Interaction Test			
Composite score of sway rate	-0.1 (0.17)	0.30 (0.28)	**<0.01**
Center of gravity alignment	-0.58 (0.12)	-0.0 (0.31)	**0.02**
Weight Shifting in Standing Test			
0° Left	0.1 (0.15)	-0.0 (0.16)	**0.03**
0° Right	0.58 (0.18)	-0.0 (0.11)	**0.02**
30° Left	0.04 (0.23)	0.03 (0.19)	0.34
30° Right	-0.0 (0.19)	-0.0 (0.19)	0.87
60° Left	-0.0 (0.19)	0.00 (0.16)	0.63
60° Right	0.14 (0.28)	0.01 (0.14)	0.81
Limits of Stability Clinical Test			
Reaction time composite	-0.1 (0.15)	-0.0 (0.19)	**0.04**
Movement speed	1.20 (2.24)	1.20 (1.65)	0.30
End-point reaching	16.7 (30.1)	20.8 (25.9)	0.75
Maximum orientation	20.3 (36.6)	26.1 (32.6)	0.87
Rhythmic Weight Shifting Test			
Right-left flow rate	0.06 (0.16)	0.07 (0.24)	0.87
Right-left direction control	0.0 (0.07)	0.09 (0.16)	0.13
Forward-backward flow rate	0.10 (0.51)	0.05 (0.27)	0.52
Forward-backward direction control	8.16 (19.0)	1.09 (1.64)	**0.03**

Δ: post-intervention–pre-intervention, SD: standard deviation

a statistically significant improvement between evaluation results in fully extended knee (0°) at both right and left sides values (z=-2.111; -2.111; p<0.05 respectively); there was no statistically significant improvement in routine physiotherapy group in fully extended knee (0°) at both right and left sides values (p>0.05); and in routine physiotherapy group there was a statistically significant improvement in 30° flexion right and left values (z=-2.002; -2.002; p<0.05 respectively). There was no statistically significant difference was between evaluations in other positions (Table 2). When the effects of the two intervention approaches on WSST were compared, it was found that TT was more effective on fully extended knee (0°) at both right and left sides (p<0.05). There was not any significant difference in other test positions (Table 3).

LoST

According to the LoST, in TT group, there were significantly difference in reaction time backward scores (z=-2.214; p<0.05), and end point reaching and maximum orientation sub-parameter of the test (z= -2.214, -2,214; p<0.05), in routine treatment group there was not any difference in any parameter of LoST when it compared before and after the treatment (p>0.05) (Table 2) When the effects of the two intervention approaches on LoST compared, improvement on reaction time composite score of TT group was significantly higher than routine physiotherapy group (p<0.05); there was not ant significant difference in movement speed, end point reaching, and maximum orientation parameters of LoST between groups (Table 3).

RWST

There were significantly differences on Right-Left Direction Control and Forward-Backward Direction Control parameters of RWST in TT group before and after the treatment (z=-2.041; -2.232; p<0.05 respectively), but not in Right-Left Flow Rate and Forward-Backward Flow

Rate parameters of RWST ($p>0.05$). In routine treatment group, there was not any significant difference in Right-Left Flow Rate, Right-Left Direction Control, Forward-Backward Flow Rate, Forward-Backward Direction Control parameters of RWST before and after the treatment ($p>0.05$) (Table 2). When the effects of the two intervention approaches on RWST, improvement reaction time composite score of TT group was significantly higher than Forward-Backward Direction Control ($p<0.05$), there was no significant difference in other test results (Table 3).

Range of motion

There were significantly improvement on ankle dorsiflexion, knee and hip extension passive ROM in TT group before and after the treatment (z=-2.271, -2.449, -2.060 $p<0.05$ respectively), but not in hip abduction. In routine treatment group, there were significant improvement in ankle dorsiflexion and knee extension. When the effects of the two intervention approaches on the ROM compared, improvement on ankle dorsiflexion, knee and hip extension of TT group was significantly higher than routine physiotherapy group ($p<0.05$); there was no significant difference in hip abduction ROM between groups.

DISCUSSION

The present study aimed to investigate the effects of TT on PC and balance in children with spastic dCP. According to the results of the study, TT added to the PRT program can enhance different aspects of PC and improve balance in children with spastic dCP.

It is well recognized that children with CP exhibit poor PC and this deficiency affects both their anticipatory and reactive PC.[8] This deficiency in PC exacerbates the limitations in gross motor skills requiring balance, especially gait.[25]

In our study, evaluating the alignment of the COG via *MCSBT* revealed that following TT, individuals shifted their COG from the front part of the base of support to the center, and this change was significant. Kurz *et al*. reported that children with spastic dCP show a diminished ability to appropriately perform mechanical work by the legs to lift and redirect the COG. The altered mechanical work performed by the legs on the COG play a role in the higher metabolic cost for walking noted in children with CP.[26] Gage and Sutherland emphasized that in children with spastic dCP, standing and walking are accompanied with disrupted pelvis and trunk alignment due to ankle equinus and increased knee flexion or extension.[10] Therefore, this change can be due to the possible impact of TT on improving the alignment of lower extremities, maintaining an upright posture, and increasing the stabilization of aligned pelvis and trunk. Moreover, in the current study, increase on composite score of *MCSBT* was higher in TT group. This indicates that treadmill is more effective in utilizing and improving somatosensory inputs such as proprioception. Cherng *et al*. reported that spastic diplegic patients standing on stable surfaces with their eyes open did not differ from their normal developing peers; however, their stabilization deteriorated with eliminated visual input or on an unstable surface.[27] This indicates that children with spastic dCP cannot overcome the sensory conflict situation. The significant increase in favor of TT in the composite score suggests that including TT to treatment program may be effective in managing inter-sensory-conflict to provide sensory organization. Similarly, El Shemy *et al*. found improvements on proprioception fallowing TT exercise in children with dCP[9]; therefore, clinically it can be say that TT can help to improve proprioception and sensory organization during balance rehabilitation in children with CP.

In the current study, we found that there were differences between the groups in different subtests of the LoST. It is known that in children with dCP, the COG displaces towards the front part of the base of support.[28] One of our important findings regarding LoST was that following TT, COG tends to transfer towards the center of the base of support. Examining subtest results shows that there were significant differences in backward reaching, reaction time, endpoint access, and maximum orientation; all of which indicate that TT can significantly contribute to PC and dynamic transfer of the COG. In their research of habilitation strategies for PC, Shumway-Cook *et al*. found that this type of balance control can be improved through training, and they demonstrated long term effects of this improvement.[29]

Many daily living activities require postural stabilization and destabilization. In an attempt to explain intuitive postural arrangements required for different functional tasks, Hirschfeld and Forssberg examined intuitive postural adjustments in walking on a treadmill and reported that active gait cycle and intuitive PC responses were modulated.[30]

Adkin *et al*. described anticipatory PC as muscle activation responses to predictable perturbations in order to provide the postural task with maximum safety.[31] Based on these explanations, we think that the change in stability limits after TT may be related to the intuitive postural responses that develop during gait cycle and arise in response to the perturbations created by the treadmill in anterior-posterior directions.

Weight transfer is one of the main components of gait pattern, but in most children with CP, the weight transfer capacity is impaired, which is also related to the impaired walking of the children with CP. Studies have reported that, compared to children with typical development, children with CP transfer weight less effectively, move their COG in a smaller range, move more slowly, and need visual support to perform movements.[32] We found significant differences in TT groups in right-left direction control composite score, forward-backward direction control and composite score. In addition to the increase in the ability to move the COG backward, the increase in forward-backward parameters of the rhythmic-weight-transfer-test indicates that TT enables children to dynamically transfer their COG. An increase in right-left direction control composite score, forward-backward direction control prior to TT shows that dynamic exercise training as in TT can be effective in improving dynamic weight transfer capacity.

Gage *et al*. states that the impairment in lower extremity alignment in children with spastic dCP causes positional lever arm dysfunction, which is indication of lack of stabilization due to muscle weakness, changes in muscle tone, as well as lack of balance and selective motor control.[10] In their study investigating the effects of TT on static and functional balance, Grecco *et al*. reported that TT was effective on balance and reduced medio-lateral sway.[33] Therefore, following TT, the decrease in the sway is related to the increase in stabilization as a result of TT.

In the WSST, following TT, there was a difference when the hip and knee were in full extension, whereas there was no difference when the knee was in flexion. This indicates the active use of extension in the hip as a result of TT. We believe that the ability to transfer COG from front to the center -as shown in the results of MCSBT also enables dCP children to overcome the flexion position commonly seen in this population. Moreover, the improvements in the passive ROM on ankle dorsiflexion, knee and hip extension may be resulted by more aligned posture that allows weight shifting. Hösl *et al*. investigated effects of backward-downhill TT versus manual static plantar flexor stretching.[34] Although, in current study TT is based on both forward and backward TT, the mechanism is the same, improving co-ordination and reducing dynamic stretch sensitivity which gives opportunity to improve ROM. We believe that improvements in ROM in knee and hip extension in TT group allow the subjects to experience weight shifting in extended lower limbs. On the other hand, large number of children in current study had knee flexion during gait and despite of TT, they experience functional activities as gait in knee flexion. This effect may be the reason of the difference on weight shifting at 30° knee flexion between groups.

It is reported that the training protocols should be combined with a functional skill/task in order to facilitate motor learning in children.[33] Recently, Seyhan-Bıyık *et al*. showed functional improvements especially on gait and functional mobility as well as muscle strength with TT following botulinum toxin injection.[15] Bjornson *et al*. also found in their pilot study, TT in different speeds improves short-term walking capacity and performance.[35] Bringing together with findings of current study, we think that TT, which is a functional method, can facilitate motor learning and can help to improve functionality of children with CP.

Studies evaluating the effects of TT on PC parameters in children with CP are limited in the literature, and mostly consist of non-randomized studies and case reports with low level of evidence. The present study is one of the few studies evaluating the effects of TT on both impairment and function of PC in children with spastic CP. This is the first study to evaluate PC with gold standard tests. Using a cross-controlled experimental design enabled us to come to more firm conclusion by ruling out individual differences in CP, which is a very heterogenous group.

TT is currently used extensively in CP clinics. Yet, there is need for more evidence in different clinical situations. Based on the results of this study, physiotherapists are recommended to include TT in their treatment protocols to improve functional balance and PC in children with CP.

The main limitation of the study is the lack of follow-ups to investigate long-term effects of the training. Long-term follow-up of changes in PC and balance is recommended in future studies. The study did not evaluate postural responses through electromyography, which is the second limitation. Future studies are recommended to evaluate muscle responses.

In conclusion, TT in addition to routine physical therapy is beneficial for postural stability, weight shifting, sensory organization during mobility as well as standing in an alignment; that are important for maintaining and improving PC, balance and functional mobility. For this reason, it may be important to add structured TT to intervention programs for ambulatory children with dCP.

DISCLOSURE

Conflict of interest: None

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