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The effect of long-term training program on balance in children with cerebral palsy: Results of a pilot study for individually based functional exercises

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This study examines the effects of long-term training program on balance and center of pressure (COP) for four male children (13 years of age) with cerebral palsy (CP). These children were classified into one hemiplegic (level II), one diplegic (level II) and two quadriplegic children (levels III and II) using the Gross Motor Function Classification System. Balance measurements (static balance: double leg and dynamic balance: single leg) were evaluated with a force platform for 30 s. In addition, Berg Balance Scale, Modified Ashworth Scale, maximum handgrip strength, modified apley test, body composition measurements were performed for all the subjects. The intervention corresponded to at least three sessions per week as a mixed training regimen for 7 months. All evaluations were repeated 3 times: One prior to the start of the training; the second one after 16 weeks and the third one after 28 weeks. Mixed training program improved performances for all the measured parameters. The greatest static balance improvement was observed in one quadriplegic child (level III) and 5 years old hemiplegia was able to stand unaffected after training. We suggest that children with CP will benefit from long-term mixed training program.

Key words: Balance, cerebral palsy, children, training, exercises, static and dynamic.

INTRODUCTION

Cerebral palsy (CP) is a non-progressive motor impairment caused by irreversible defect or lesion in immature brain (Liao et al., 1997). It causes activity limitation and postural disturbances. Children with CP have poor postural control and they encounter problems during static upright standing in altered sensory integration, and this lead to the delays and deviations in motor skill acquisition and development (Donker et al., 2008). In particular, children with CP have difficulties with activities such as walking independently, running and climbing stairs (Verschuren et al., 2008), because of their low level of physical activity (Zwier et al., 2010). Purposes of exercises and rehabilitation programs are to increase general physical capacity and functional independence for children with cerebral palsy (Dodd et al., 2003). However, generally, all over the world, while clinic rehabilitation programs are recommended for these children, sports and recreational activities were not enough (Verschuren et al., 2008; Zwier et al., 2010). Recreational level of sport activities with specific balance and strength training may provide great contributions to the development of functional skills such as postural balance, coordination, speed, and quality of gait (Dodd et al., 2002).

Postural control may require two main features: a) keeping the position of a part of body in relation to the body itself or to the environment b) maintaining the position of all the body on relation to its center of mass

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Table 1a. Subjects' demographic values (Subjects' age, diagnosis and GMFCS level).

Subjects	Age (Year, month)	Diagnosis	GMFCS pre-test	GMFCS post-test
S1 (H1)	5 y, 6 mo	Spastic Hemiplegia	Level II	Level I
S2 (D2)	10 y, 5 mo	Spastic Diplegia	Level II	Level II
S3 (Q3)	8 y, 6 mo	Spastic Quadriplegia	Level III	Level III
S4 (Q4)	13 y, 2 mo	Spastic Quadriplegia	Level II	Level II

(COM) with respect to the environment (Latash, 1998). The body's COM is the point at which mid sagittal, mid-frontal and mid-transverse planes intersect. Stability of human upright posture is ensured provided that the vertical projection of the COM falls within the base of support (BOS) during stance (Patla, 2003). Any alteration in the motion of a body segments leads to a change in the location of the COM of the body (Chang et al., 2011). The COP area is the point where resultant ground reaction force that supports the surface is applied to the body. Postural balance is frequently assessed by the quantitative analysis of COP trajectories as measured with a force plate (Donker et al., 2008; Thompson et al., 2008; Ledebt et al., 2005). The COP reflects both movement of the COM and active forces exerted by the feet on the force plate (Van et al., 2002). Proper balance requires integrating information from different sources vestibular, visual and proprioceptive information (Latash, 1998). Balance control ability consists of static and dynamic balance, sensory organization and movement co-ordination (Liao et al., 1997).

Children with CP have some neuromuscular deficits; impaired motor control, the existence of abnormal muscle tone, musculoskeletal restriction such as bony deformities, an imbalance between agonist and antagonist muscles, impaired sensory deficits and weakness (Shumway-Cook et al., 2003; Hsue et al., 2009). Because of these postural problems, children with CP have an insufficient physical activity level and these children need to be physically active every day of the week, at least one hour duration (Zwier et al., 2010). Strength and balance training programs are important component of rehabilitation programs and may improve motor activity for children with CP without adverse affect (Ledebt et al., 2005; Dodd et al., 2002). In school age children with hemiplegic (one of the impaired side), the effects of balance training with visual feedback have been examined; 6 weeks training improved the performances on the tasks that were trained during quit standing, and the walking pattern became more symmetrical after training (Ledebt et al., 2005). A relatively short (4 weeks) program of specific strengthening exercise task and training for diplegic (two limbs impaired) and quadriplegic (four limbs impaired) spastic children have resulted in improved strength and functional performance, which was maintained over time (8 weeks) (Blundell et al., 2003).

The main aim of the present study is to examine the effects of long-term (7 months or 28 weeks) training programs on recovery of postural control, functional balance, ankle spasticity, handgrip strength and shoulder flexibility. A secondary aim is to test whether the effects of the exercises on the progress of the child were increasing linearly over time. For these purposes, training programs were designed individually and combined with balance, strength, flexibility, coordination and swimming exercises.

RESEARCH METHODS

Subjects

Four male children with CP between 5 and 13 years of age were included in this study. The children were classified using the Gross Motor Function Classification System (GMFCS) at the beginning of the study. 1 spastic hemiplegia, 1 spastic diplegia and 2 spastic quadriplegia children participated in this study. GMFCS rates of children are shown in Table 1a. We examined the BMI and body fat as measured by bioelectrical impedance with Tanita SC-330 (body composition analyzer) in subjects (Table 1b); inclusion criteria are: (1) no surgery or botuline toxin treatment on the proceeding 6 months (2) no history of uncontrolled seizures or vestibular dysfunction, (3) no uncorrected vision or hearing impairments, (4) to understand experimental procedures and to be able to do exercises (5) participation in a training program regularly. For all the subjects, right side was the dominant extremity. The Marmara University Ethics Committee approved the study and written consent form was signed by all the children' parents or guardians.

Instrument

Balance measurements were evaluated when the subjects stand quietly on a force and balance plate (432 × 368 x 5 mm), which measured vertical ground reaction forces. TekScanMatScan® system (model 3150, Boston, MA) was used with scanning speed of 100Hz. Low profile floor mat contains 2.288 individual pressure-sensing locations (1.4 sensel/cm^2), and is connected to a data acquisition system controlled by the software version 6.34. The Center of force (COF) data are automatically estimated (calculated) by the system's software. In this study, COF is equal to center of pressure (COP). Force measurements were taken at a sampling rate of 30 per s. The procedure for calibration was conducted according to the manufacturer's instruction and *matscan* pressure mat software was used for the interpretation of the data. COP area outcome variables were taken during balance recording: COP-area; the region (elliptical space) in which the COP traveled (www.tekscan.com/medical/pressure-sensitive-mat.html).

Procedure

Gross motor function

In this study, all children were classified according to GMFSC in the

Table 1b. Subjects' anthropometric and body composition measurements.

Subjects	Time	Height(cm)	Weight (kg)	BMI	Fat (kg)	Fat (%)	Mass (kg)	Water (kg)
S1	15 May	113	20.4	16	3.8	18.6	16.6	12.2
	15 December	117	24.5	17.9	5.7	23.2	18.8	13.8
S2	15 May	137	34.9	18.6	9.5	27.3	25.4	18.6
	15 December	137.5	38.6	20.6	11.7	30.4	26.9	19.7
S3	15 May	122	24.6	16.5	7	28.3	17.6	12.9
	15 December	123	27.3	18.1	9.4	34.3	17.9	13.1
S4	15 May	151	41.9	18.4	9.4	22.5	32.5	23.8
	15 December	158	45.7	18.3	6.1	13.3	39.6	29

15 May: Pre-test (1^{th} Day); 15 December: Post-test (28^{th} week); Mass: Lean Body Mass; Water: Total Body Water.

beginning of the training program and followed during training program. The Gross Motor Function Classification System (GMFCS) for cerebral palsy was used to classify level of functional limitations in daily life in children with cerebral palsy (Palisano et al., 1997). It is based on self-initiated movement with an emphasis on sitting control, transfers and walking. The GMFCS describes a five level scale, which rates a child's gross motor function: from level 1 (most functional) to level 5 (most restricted). GMFCS level would be to alter with physical therapy, exercise or training over time (Bodkin et al., 2003; Wood and Rosenbaum, 2007).

Matscan (Force platform)

For the balance measurements, the following test conditions were performed in bare-foot: Static balance: Eyes Open with double limb (EO), Eyes Closed with double limb (EC); Dynamic balance (single leg) measurements (EO and EC): only hemiplegic spastic child could stand on unaffected side (EO condition). In all conditions, children with CP balanced for 30 s while COP data were collected. The children were previously instructed to maintain posture during recording process and one practice trial was done before the beginning of data collection. For each condition, measurements were repeated three times to obtain a mean value. A period of 1 min rest was allowed between the trials in sitting position. The children were placed to stand position in the mat with keeping a distance between the feet similar to the distance between the shoulders in order to enable the foot position to be repeated from the trials (Bigongiari et al., 2007). In order to minimize head movement and prevent vestibular disruption, participants were instructed to focus on the center of a visual target. The visual target, rectangular 2 cm green spot, was positioned at a distance of a 2-meter at the height of the eye level of each child (Brenton-Rule et al., 2012).

In addition to balance parameters evaluations with force platform, functional balance (Berg Balance Scale), spasticity level (The Modified Ashworth Scale), maximum handgrip strength, modified apley test (shoulder flexibility test) were performed for all the subjects. All evaluations were repeated 3 times: One prior to the start of the training (pre-test; 1^{th} day); the second one at 16^{th} week (mid-test) and the third after 28^{th} week (post-test).

Functional balance

The Berg Balance Scale (BBS) is used for evaluation of functional balance abilities children with CP. This has 14 items of increasing difficulty for testing functional skills relevant to daily life activities from sitting to one leg stance. Each item is scored on a five point ordinal scale ranging from 0 to 4 points, with a maximal score level of 56. A higher score shows better postural balance. The items are executed within specified amount of time and test duration takes approximately 20-30 min depending on the child's functionality (Kazon et al., 2012; Kembhavi et al., 2002)

Handgrip test

Digital handgrip dynamometer (Takei A5401) was used to record the maximal grip strength between the test evaluations. The handgrip tests were performed with the children sitting in a chair in an upright position. The shoulder was flexed at 45 degree with full extension in the elbow. Subjects put their forearm on a table, with their hand in a semi-pronated position. Children with CP were asked to perform three maximal hand contractions with 2-min rest intervals between them.

Spasticity Evaluation: The Modified Ashworth Scale (MAS)

The Modified Ashworth Scale (Table 2) was used to evaluate spasticity level between training sessions. Spasticity can be defined simply as an increased muscle tone due to exaggerated stretch reflexes. It can cause especially increased ankle stiffness because of muscle shortening in the lower limb for children with CP (O'Dwyer et al., 1996). MAS is used to measure spasticity and performed manually to assess the resistance of muscle to passive stretching (Bohannon andSmith, 1987).

Modified Apley Test

The modified apley test is designed to measure upper-body flexibility: this test requires shoulder flexion in combination with abduction and external rotation. "Subjects attempted to reach back and touch with one hand the medial angle of the superior medial angle of opposite scapula" (Short and Winnick, 2005). This action is critical for many daily living activities. One trial was given for each arm in the test sessions.

Training procedure

Training programs were performed individually for each subject. All exercise frequencies corresponded to at least three sessions per week during 7 month. Each exercise session took between 60 and

Table 2. The Modified Ashworth scale (MAS) (Bohannon and Smith, 1987).

0 (0)	No increase in muscle tone.
1 (1)	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension
1+(2)	Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the reminder (less than half) of the ROM (range of movement)
2 (3)	More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved.
3 (4)	Considerable increase in muscle tone passive, movement difficult.
4 (5)	Affected part(s) rigid in flexion or extension

Source: http://www.neurosurvival.ca/ClinicalAssistant/scales/ashworth.html.

Table 3. Exercises within the training program for children CP.

Balance	Strength	Flexibility	Coordination	Swimming
*Single leg balance with bar *Balance on Pilates ball *Wobble board training *Balance walking on rope *Balance exercise with different floor styles *Weight-bearing exercises *Supported/Unsupported side walking *Forward and backward walking *Walking in a stride line	*Curl up, half push-up * Bilateral half squat; Sit to stand, Lateral step-up *Back extension *Rope hanging and climbing *Wobble board training *Climbing wall exercises *Upper and lower extremity extremity flexion, extension, abduction, adduction *Knee flexion, extension *Passing over barriers *Walking up and down on stairs * Ankle dorsi-plantar flexion *Lateral step-up and step -downs	*Upper extremity ROM exercises *Lower extremity ROM exercises * Trunk flexibility exercises	*Field exercises with different materials (example, cross step-over walking, passing different obstacles, mirroring each other's movements) *Picking up balls from dart *Ball throwing to target	Once or twice a week for one hour

75 min. Training load increased gradually to get progression and some exercises were modified according to children's physical abilities. Subjects were also able to attend their routine physical therapy program around 45 min once a week. The training programs were given by *the disability sport specialist*. Exercise loadings were applied approximately with the following duration: Strengthening exercises (20-30 min), balance exercises (15-20 min), flexibility (10 min) and coordination exercises (15 min). Training programs were increased progressively from 1 to 3 sets of each exercise with 8 to 14 repetitions.

Training regimen and sport activities consist of the following tasks (Table 3): static and dynamic balance tasks, ball activities, coordination, strength (push-up, sit-up, etc…), flexibility, and swimming exercises (each week one day). In addition to these activities, climbing and walking exercises were used to improve functionality of children (such as rope net climbing, wall climbing and tight rope walking) (Figure 1).

Data analysis

All measured data were indicated as a unique value for each assessment session (pre-test, mid-test and post-test) under the results section. The percent change of balance (COP amplitude increase or decrease rate), handgrip strength, BBS test values was calculated between pre-test and 16th week; pre-test and 28th week during training period. MAS and Modified apley tests scores were rated as a number for each test sessions during training period.

RESULTS

Force platform balance measurement

Hemiplegic subject's EO-COP area amplitude values were decreased after 16 weeks of training. There was a positive change in EO-COP area after 28 weeks of training but the change was less than 16th week value (Table 4a). COP areas of EC condition after 28 weeks of training was better than pre-test and 16th week assessments.

As with other subjects, hemiplegic child failed to complete dynamic balance test (EO condition) with both unaffected and affected side at pre-test. However, he was able to complete the single leg balance test (EO) on unaffected side after 16 weeks of training. In the second period of training (following 12 week), EO-COP area amplitude was not reduced as a linear trend on unaffected side. He was not able to complete the single leg

Figure 1. Some physical activity samples for children with cerebral palsy.

Table 4a. Subjects' force platform results (Hemiplegic subjects' force platform balance results and %change between 1th day and 16th week; 1th day and 28th week during training program).

Subject 1 (H1): Spastic hemiplegia, GMFCP level (II-I)				
Condition		**Test time**	**COP area (cm^2)**	**%change**
Static balance	EO (Double Leg)	1 Day	6.95	
		16 Week	2.483	65.55
		28 Week	3.845	44.68
	EC (Double Leg)	1 Day	13.3	
		16 Week	6.117	54.01
		28 Week	2.183	83.59
Dynamic balance	EO (LL) Left Leg	1 Day	Failed	
		16 Week	6.191	X
		28 Week	7.554	-20.1
	EO (RL) Right Leg	1 Day		
		16 Week	Failed	
		28 Week		

LL: Left Leg; RL: Right Leg;* Positive values under % change column indicate improvement for the COP area.

leg balance test (EO) on affected side during training period and he also was not able to perform EC-single leg condition test for 30 s on both affected and unaffected side.

Subject 2 COP area values of EO condition were improved (reducing COP amplitude) after 16 weeks of training. There was a positive change in EO COP area after 28 weeks training but less than 16th week value (Table 4b). EC condition COP area values deteriorated after 16 weeks training but there was a minimal improvement following 28 weeks of training. 28 weeks of training was not enough to improve right and left single leg balance ability.

Subject 3(Q3) could not complete 30-s static balance test on double limb for EO and EC condition in pre-test assessment. After 16 weeks of training he was able to complete the test and improved static postural balance after 28 weeks of training. However, there was no improvement for single leg static balance after training (Table 4c).

For Subject 4(Q4), a minimal improvement was observed in COP area for EO condition after 28 weeks of training (Table 4d). There was no improvement for COP area of EC condition after 16 weeks training but subject displayed approximately 27% rate of positive changes after 28 weeks of training. Subject 4 (Q4) was not able to complete single leg stance test like the other quadriplegic and diplegic subjects after 28 weeks of training.

The berg balance scale (BBS)

Functional balance or BBS scores had increased for all children with CP after 16 weeks of training, but improvements were minimal for functional balance following 12 weeks of training (Figure 2). There was no direct proportion of increase for quadriplegic children after they have reached a certain level of functional balance abilities. After 28 weeks, BBS enhanced by 21% for H1 (S1), 21% for D2 (S2), 75% for Q3 (S3) and 17%

Table 4b. Diplegic subject' force platform balance results and %change between 1th day and 16th week; 1th day and 28th week during training program.

Subject 2 (D1): spastic diplegia, GMFCP (II)				
Condition		**Test time**	**COP area (cm^2)**	**%change**
Static balance	EO (Double leg)	1 Day	7.174	
		16 Week	2.993	58.28
		28 Week	4.49	37.41
	EC (Double leg)	1 Day	4.656	
		16 Week	7.54	-39.1
		28 Week	3.992	14.26
Dynamic balance	EO (Left leg)	1 Day		
		16 Week	Failed	
		28 Week		
	EO (Right leg)	1 Day		
		16 Week	Failed	
		28 Week		

*Positive values under % change column indicate improvement for the COP area.

Table 4c. Quadriplegic subject' (GMFCP-level III) balance results and %change between 1th day and 16th week; 1th day and 28th week during training program.

Subject 3 (Q3): Sapastic Quadriplegia, GMFCP (III)				
Condition		**Test time**	**COP area (cm^2)**	**%change**
Static balance	EO (Double leg)	1 Day	Failed	X
		16 Week	7.097	
		28 Week	5.199	26.75
	EC (Double leg)	1 Day	Failed	X
		16 Week	15.69	
		28 Week	9.641	38.55
Dynamic balance	EO (Left leg)	1 Day		
		16 Week	Failed	
		28 Week		
	EO (Right leg)	1 Day		
		16 Week	Failed	
		28 Week		

*Positive values under %change column indicate improvement for the COP area.

for Q4 (S4) (Table 5). The greatest development was observed in quadriplegic child (GMFCP level III) in terms of functional balance and daily living activities.

Hand grip strength

Figure 3 shows a comparison of the training sessions for subjects. Hemiplegic subject (S1) could not improve his handgrip strength for the affected side, but there was an increase of 134.6% strength for unaffected side after 28 weeks strength and other exercises. Diplegic subject (D2) displayed a minimal positive change of 6.3% for left and 4.35% for the right hand grip strength training. Grip strength increased in both left (S3: 68.66%; S4: 90.14%) and right (S3: 58.82%; S4: 52.98%) hand for two quadriplegic subjects (Table 5).

Modify Apley and MAS scores

Modified apley test: all of the subjects could touch their top of the head (score: 2) at the beginning of the training program. While right hemiplegic subject was able to

Table 4d. Quadriplegic subject' (GMFCP-level II) balance results and %change between 1th day and 16th week; 1th day and 28th week during training program.

Subject 4 (Q4): Sapastic Quadriplegia, GMFCP (II)				
Condition		**Test time**	**COP area (cm^2)**	**%change**
Static balance	EO (Double leg)	1 Day	11.33	
		16 Week	9.562	15.60
		28 Week	10.1	10.86
	EC (Double leg)	1 Day	14.44	
		16 Week	15.39	-6.58
		28 Week	10.43	27.77
Dynamic balance	EO (Left leg)	1 Day	Failed	
		16 Week		
		28 Week		
	EO (Right leg)	1 Day	Failed	
		16 Week		
		28 Week		

*Positive values under %change column indicate improvement for the COP area.

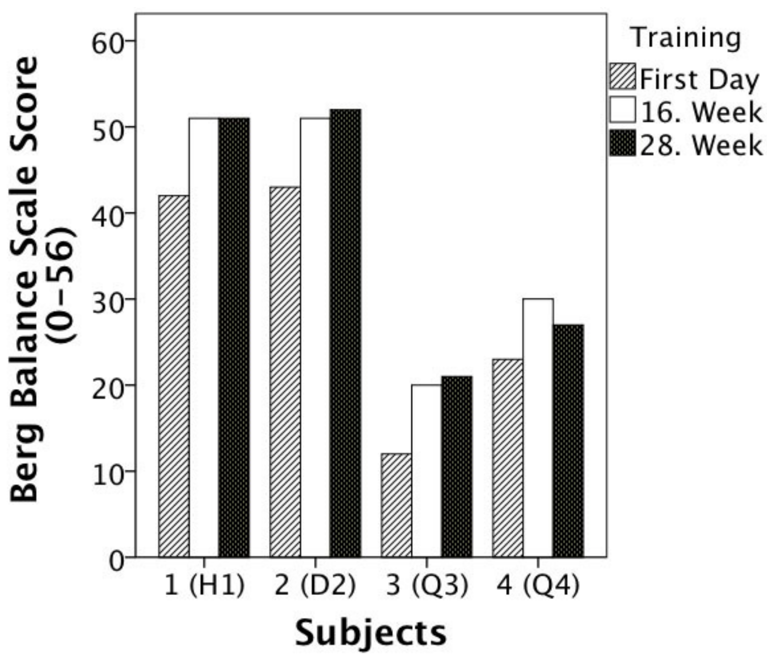

Figure 2. Subjects' BBS test scores during training program.

touch the superior medial angle of his left side of scapula (score: 3) with his right hand after 28 weeks, other children were able to do this after 16 weeks of training.

For all children, shoulder stretch test was completed successfully after 28 weeks of training for both right and left hands (Table 6).

Modified Ashworth scale: Plantar flexor spasticity of children with CP had been decreased after 16 weeks of an exercise program. The training for the period of 16 weeks to 28 weeks did not induce a decrease in the calf muscle tonus (Table 6). A plateau was observed at the assessment of 28 weeks of training. The spasticity level (2) according to MAS scale of hemiplegic subject decreased after 16 weeks of training, but it did not improve even though he continued the training program and his MAS score went back to the pre-test level in the 28th training week.

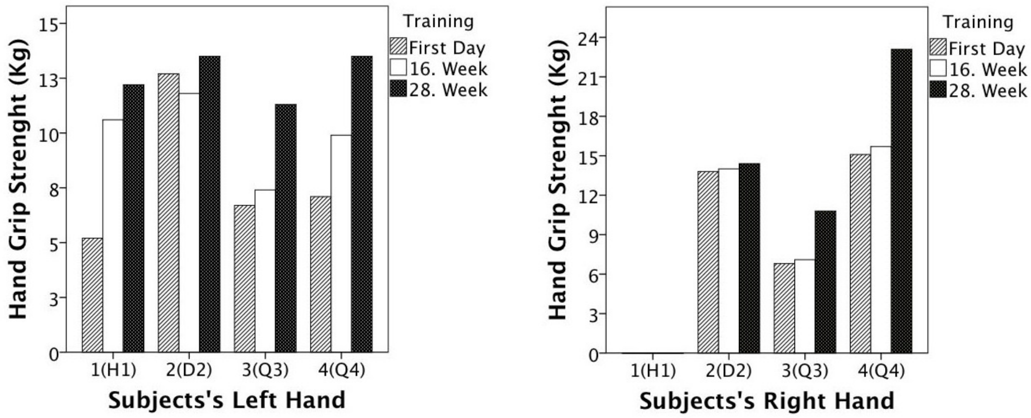

Figure 3. Subjects' right and left hand grip test results during training program.

Table 5. Handgrip strenght (kg) and berg balance scale (BBS) results and %change between 1th day and 16th week; 1th day and 28th week during training program.

Subjects	Test time	BBS	% change	Grip Left (kg)	% change	Grip right (kg)	% change
	1 Day	42		5.2		Failed	
S1(Right Hemiplejia)	16 Week	51	21.43	10.6	103.83	Failed	X
	28 Week	51	21.43	12.2	134.60	Failed	X
	1 Day	43		12.7		13.8	
S2(Diplegia)	16 Week	51	18.60	11.8	-7.09	14	1.45
	28 Week	52	20.93	13.5	6.30	14.4	4.35
	1 Day	12		6.7		6.8	
S3(Quadriplegia)	16 Week	20	66.67	7.4	10.45	7.1	4.41
	28 Week	21	75.00	11.3	68.66	10.8	58.82
	1 Day	23		7.1		15.1	
S4(Quadriplegia)	16 Week	30	30.43	9.9	39.45	15.7	3.97
	28 Week	27	17.39	13.5	90.14	23.1	52.98

DISCUSSION

Very little research has been conducted on the effect of long term training program especially balance ability, spasticity level and handgrip strength of children with CP. Zwier et al. (2010) emphasized the need to encourage and maintain training programs or sports in children with CP to enhance their daily life activities. In the literature, the strength-training effects have been reported frequently for the lower extremity strength exercises (Dodd et al., 2002; Shumway-Cook et al., 2003) rather than upper extremity or whole body strength exercises (Verschuren et al., 2008). We preferred to investigate the effect of a mixed (combined) exercise program (balance, strength, flexibility, coordination with swimming training) on children with CP. Furthermore, in this training program, in addition to lower extremity exercises, upper extremity and trunk exercises were included.

Force platform balance measurement

The results of the present study suggest that mixed training with balance training might be useful to decrease the amplitude of COP area for especially static balance. There was a general trend that the mean area of COP (COP amplitude) was reduced in these children as a result of 16 weeks training. For the 12 weeks training after this 16 weeks training, in general there was not further decrease in COP area amplitude significantly, but gained balance ability was maintained in children with CP. Thus, this study showed that these children need long-term exercise programs to improve balance ability.

For hemiplegic children with CP, benefits of training have reached to a certain level after 16 weeks during EO

Table 6. Subjects' modified apley test and MAS results between 1th day and 16th week; 1th day and 28th week during training program.

Subject	Test time	Modified apley test (shoulder flexibility)		MAS (Plantar flexor spasticity)	
		Right	Left	Right	Left
	1 Day	2	3	3	X (Healthy)
S1(Right Hemiplejia)	16 Week	2	3	2	X (Healthy)
	28 Week	3	3	3	X (Healthy)
	1 Day	2	2	4	4
S2(Diplegia)	16 Week	3	3	3	3
	28 Week	3	3	3	3
	1 Day	2	2	4	4
S3(Quadriplegia)	16 Week	3	3	3	3
	28 Week	3	3	3	3
	1 Day	3	2	1	2
S4(Quadriplegia)	16 Week	3	3	1	2
	28 Week	3	3	1	2

condition in the static balance and there was no linear increment in the values comparing 16 weeks to 28 weeks. It can be concluded that it is important to continue training program to keep subjects' balance ability, gained with exercises. Extending the time of training has improved the static balance in EC condition and the subject has reached a similar COP area value like EO condition at the end of 28 weeks. These findings indicated that the greatest progress has been provided in the closed eyes condition with a specific training program in terms of static balance. Training has induced a positive change in balance for unaffected side but it reached a plateau after 16 weeks of training. When we compared COP area changes, this subject had obtained the most benefit on single leg stance after training program. The 6-year-old spastic hemiplegia child gained the ability to stand on the unaffected limb after 4 months training in opened eyes condition; 7 months training was not sufficient to ensure a dynamic balance ability on the affected limb for the single leg standing.

Outcomes of this study showed that motor ability shifted one upper level only for hemiplegic subject. The right hemiplegia child diagnosed as level II according to the GMFCP in the beginning of training program raised up to level I after 7 months. Research by Shumway-Cook et al. (2003) reported evidence for the children with spastic hemiplegia have faster improvement for basic performance after training program comparing to the children with spastic diplegia. Our balance results, which compared hemiplegic and diplegic subjects, are also consistent with the literature. It was suggested that children with spastic diplegia might need prolonged training in recovering postural control to display similar improvements to children with spastic hemiplegia (Shumway-Cook et al., 2003).

Subject Q3 that is one of the spastic quadriplegic subjects was included in the training program 7 months after a hip surgery, which was intervention of releasing bilateral hamstring and rectus femoris muscles. This subject obtained the 30-s static balance control after 16 weeks training program which consisted of one-day physiotherapy and three-day exercise per week. These findings suggested that sport activities in addition to physical therapy program could accelerate improvement in static balance ability after surgical intervention. Moreover, in the 9-year-old spastic quadriplegic subject (S3: level III) who had began to mobilize, the improvement of static balance had increased in parallel to training time for both conditions EO and EC. Formerly, ambulated 13-year-old quadriplegic subject (S4) who has level II had not shown an improvement for static postural balance during EO condition in parallel to training time. However, for EC condition, positive improvements in static balance could be obtained after 28 week training. These findings might show that physical training program provides more effective and faster gains for the improvement of static balance in the childhood comparing to adolescence.

Berg balance scale

As balance ability is an important part of gross motor abilities, poor balance causes difficulties with functional tasks involved in activities of daily living (Gan et al., 2008). In this study, 16-weeks physical activity program with balance training had facilitated general motor functions in children with CP. However, the other functional limitations remained or improved very little for the following 12 weeks training such as single leg standing with affected extremities. Fast improvement of functional balance is difficult without decreasing muscle spasticity. Moreover, muscle strength and range of motion should be increased for all extremities. Hemiplegic and diplegic children had higher BBS score than the quadriplegic ones, because quadriplegic children had greater motor deficit and balance impairments.

Handgrip and strength training

Our results demonstrate that handgrip strength had increased during 28-week period (7 month) for these 4 participants with CP. However, hemiplegic subject was unable to grasp handgrip device with affected hand during 28-week training period. One study showed that improvement in hand takes over a longer time than commonly would be estimated (Eliasson et al., 2006). Therefore, improvement may not have been apparent for handgrip strength with 7 months of training. Furthermore, there were some limitations in our study. For example, specific hand training was not included, and some manual hand functions (that is, picking up small objects, moving heavy cans) were not evaluated. Maybe, some hand functions could have been developed for affected side during this training period. Fedrizzi et al. (2007) suggested that only the affected handgrip assessment is not sufficient to evaluate the real disability in children with hemiplegia and assessing spontaneous hand use in bilateral manipulation is required. Moreover, intensive training focused on bilateral hand function should be performed in the early years for children with hemiplegia. For the quadriplegic subjects, the improvement was more marked in hand grip strength in the second session training period than the first 16-week training. This result showed that long time progressive physical training might lead to increasing trend for handgrip strength especially for quadriplegic children.

9-year-old quadriplegic child was able to stand at the end of the 16 weeks training, and he was able to begin to take 8-10 steps without support for the first time at the end of the 28-week physical activity-training program. Furthermore, 6-year-old hemiplegic child was able to stand on unaffected foot after completing 16-week training program. These indicate that this combined (mixed) exercise program may have also beneficial effects on lower extremity strength, walking, balance ability and other movement functions. In this study, we evaluated only improvement of static and dynamic balance instead of lower extremity strength.

Modified Ashworth scale and Modified Apley test

Results of this study demonstrate that there was a decline in the spasticity of plantar flexor muscles after 16 weeks training. However, the muscle tonus did not decrease linearly along with the following 12 weeks training program. There was a similar reduction in the COP area values of the force platform measurements after 16 weeks of training. Recovery of postural control following 12 weeks training did not increase linearly and finally reached a plateau with the results of MAS. Plantar flexor muscles play an important role in postural balance (Hsue et al., 2009). The consistency of static balance and MAS assessments in our study might be due to change of calf muscle tonus. In the literature, there was some discrepancy about MAS results: while one study reported that measured muscle spasticity has reduced with strength training, the other one reported no change with strength and flexibility training (Dodd et al., 2002). This could be because training duration of these studies was shorter (8 weeks) and short-term training programs might not be enough to evaluate muscle spasticity.

Besides, shoulder flexibility (range of motion) of subjects has been completely improved after 28 weeks training. Improved flexibility has long been considered the most vital training goal for youngsters with CP, because it facilitates the performance of daily living activities and improves postural balance, mobility and independence (Short and Winnick, 2005).

There are some limitations in our study. Only four children with CP participated in the study for a long term training program and these children had different characteristics in terms of motor impairment. Next studies should include more subjects who have similar motor deficits.

Conclusion

The findings of the present study showed that children with CP have improved their static postural balance, functional balance, muscle strength and flexibility in response to individual training program after 7 months training. It is likely that these children will benefit from long-term mixed training program. These specific training programs have played a significant role for improvement of their functional abilities and independence.

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