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Effects of biofeedback treatment on gait in children with cerebral palsy

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Abstract

Purpose: We evaluated the effectiveness of biofeedback treatment on gait function in children with cerebral palsy.
Method: Thirty-six children with spastic cerebral palsy and dynamic equinus deformity were included in the study. The biofeedback group consisted of 21 children who each received EMG biofeedback training plus conventional exercise programme. The control group consisted of 15 children who each received conventional exercise programme only. Active range of motion of the ankle joints, muscle tone of plantar flexors, and gait function of the children were evaluated and compared.
Results: The biofeedback group displayed statistically significant improvements regarding tonus of plantar flexor muscles and active ROM of ankle joints ($p < 0.000$ for all parameters). Gait function showed statistically significant progress in both of the groups, but the biofeedback group was superior to controls.
Conclusions: Children with **c**erebral palsy and dynamic equinus deformities may benefit from biofeedback treatment for ambulation.

Introduction

Cerebral palsy (CP) is caused by static lesion to a developing nervous system that primarily affects motor function. Spastic motor involvement is characteristic of most of these individuals. Children with spasticity caused by CP show co-activation of agonist and antagonist muscle groups. A spastic muscle or group of muscles may overpower antagonists that less spastic, normal, or flaccid. This in turn may cause soft-tissue and skletal changes. Lower limb involvement is most apparent at the ankle joint. Dynamic equinus is a common deformity that worsens the ambulatory ability of both diplegic and hemiplegic conditions. The plantar flexors often co-activate with, and overpower tibialis anterior during swing, producing initial ground contact with the toe, rather than the heel.

Biofeedback is a method of treatment that uses electronic or electromechanical instruments to properly measure, process and feedback to individuals in the form of auditory and/or visual feedback signals by using information about their normal and/or abnormal neuromuscular or autonomic activity. Biofeedback treatment is used to help individuals develop greater awareness of and an increase in voluntary control over their physiological processes that are otherwise involuntary and unfelt events. In rehabilitation although EMG biofeedback is the most widely used technique, others such as positional, angular, pressure, temperature biofeedback systems have also been successfully used.[1–4] EMG biofeedback has gained a firm place in the treatment of upper motor neuron lesions, particularly in retraining muscles and inducing relaxation of spastic muscles.[5–7] It is also used in musculoskeletal problems like patellofemoral pain, temporomandibular disorders, postsurgery of meniscus and anterior cruciate ligament tears.[8–11]

In CP, EMG biofeedback has had little application, with no major controlled studies. Nash *et al.*[12] applied biofeedback treatment to control spasticity for three children with spastic diplegia at risk for contractures. They reported that after a 10-week training period, spasticity in the gastrocnemius muscle decreased significantly. Toner *et al.*[13] studied the effect of biofeedback training on ankle joint function in children with CP and reported significant increases in active range of motion (ROM) and dorsiflexor strength, suggesting that biofeedback treatment can improve ankle function. O'Dwyer *et al.*[14] applied feedback to 15 CP

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patients aged 6 – 19 years to reduce spasticity and contracture of the triceps surae muscle. Although they found a significant effect in reducing spasticity, no changes were observed in the degree of muscle contracture. The authors commented that reduction of spasticity has no clinical value and the most effective strategy for reversing muscle contracture might be the utilisation of procedures that lengthen the muscles combined with biofeedback training to maintain the achieved muscle length.

In this study, we applied EMG biofeedback to dorsiflexors and plantar flexors of the ankle joint in children with CP who also had dynamic equinus deformities in order to observe any improvement that may be obtained in the gait function.

Materials and methods

PARTICIPANTS

Thirty-six children with spastic CP were selected from CP patients who attended the University of Kocaeli, Medical Faculty, Department of Physical Medicine and Rehabilitation. The inclusion criteria were as follows: children must, (a) be at least 5 years old, (b) be diagnosed as diplegic or hemiplegic CP with dynamic equinus deformity secondary to calf spasticity, (c) have toe-walking gait pattern, (d) have no static deformity at the both lower extremities, (e) be able to walk independently with or without a walking aid, (f) have normal hearing and vision capability (with or without corrective glasses), (g) have normal intelligence, (h) be motivated to participate in the study, and (i) have no other significant health problems. Informed consent was obtained from the parents and the study was approved by the hospital's ethics committee.

Children were randomly assigned into two groups. The biofeedback group consisted of 21 patients who each received EMG biofeedback training for 30 min/day plus conventional exercise programme for 2 h/day. The control group consisted of 15 patients who each received only conventional exercise programme for 2.5 h/day. The duration of the treatment was 10 days for each of the group.

EVALUATION

The patients were evaluated the day before the treatment starts, at the 10th day, 1st and 3rd months. The evaluations served to measure systematically: (a) active range of motion (ROM) of the ankle joints; (b) muscle tone of plantar flexors; and (c) gait function. The active ankle ROM was tested separately when the knee joint was both in extension and flexion in a supine position for dorsiflexion by a standard manuel goniometric technique. Muscle tone was rated by the Ashworth Scale. Gait function was revealed by Clinical Gait Assessment (CGA), which is given in detail in table 1 and temporal distance factors (velocity, cadence, stride length) with videotape analysis.[15] CGA Score was determined by evaluating body parts kinematically in swing, initial contact, stance, and terminal stance phases of gait. Each item is scored by 0 = absent, 1 = minimum default, 2 = excessive default. The data was collected five times in every evaluation for each child. After excluding minimum and maximum values, the mean or median value was calculated for each parameter. All the evaluations were made by the same observer who was blind to treatment category of the patients.

TREATMENT

Conventional physical therapy approach aimed to improve the dorsiflexion range of ankle joint, and to increase control and stability in the performance of gait-related activities. ROM of the ankle joint, strengthening exercises for tibialis anterior muscle, streching exercises for gastrocnemius-soleus muscles, balance and coordination exercises, and gait training exercises constituted the conventional exercise programme.

EMG biofeedback training was applied with the Myomed EMG biofeedback instrument to both of the lower limbs of diplegic patients and affected side of hemiplegic patients. Dorsiflexor and plantar flexor activity of the ankle joint was monitored by visual (a curve or a bar graph) and audial feedback signals. The subjects performed exercises consisting of contraction of the tibialis anterior and relaxation of the spastic triseps surae muscles with EMG feedback from those muscles. During the first three sessions, one of our physical therapists described the required muscle action to the children by explaining and showing them the corresponding feedback signals.

STATISTICAL ANALYSIS

Demographic results were descriptive and expressed as percent or as mean $\pm$ standard error. Comparison of the baseline, 10th day, 1st and 3rd month measurements of ankle ROM, spasticity and gait function were performed using Friedman test. All comparisons between independent group means were applied by Mann-Whitney U test.

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Table 1 Clinical gait assessment

(A) Swing Phase:		Foot:	initial contact by anterior lateral side
Trunk:	Anterior bending		lateral side
	Posterior bending		medial side
	Lateral bending		foot flat
	Rotation		heel, drop foot
Pelvis:	Elevation to one side		heel, excessive dorsiflexion
	Retraction	(C) Stance Phase:	
	Limited anterior rotation	Trunk:	Anterior bending
Circumduction			Posterior bending
Hip:	Limited flexion		Lateral bending
	Excessive flexion		Rotation
	Limited extension	Pelvis:	Retraction to one side
	External rotation	Hip:	Limited extention
	Internal Rotation		External rotation
	Abduction		Internal rotation
	Adduction		Abduction
Scissoring			Adduction
Knee:	Limited flexion	Knee:	Hyperextension
Foot:	Varus		Excessive flexion
	Valgus		Unstable knee
	Equinus	Foot:	Plantar flexion
	Excessive dorsiflexion		Dorsiflexion
(B) Initial contact:			Varus
Pelvis:	Limited anterior rotation		Valgus
Knee:	Limited extention	(D) Terminal stance:	Limited push off
	Hyperextension		

Results

There were nine diplegic and twelve hemiplegic, seven diplegic and eight hemiplegic children in the biofeedback and control groups, respectively. Three of the children in the biofeedback group did not participate the third month evaluation. Four of the children in the control group did not continue the treatment and were counted as drop-outs. The study was stopped for the control group when the first month evaluation showed insufficient improvement comparing to the biofeedback group and biofeedback application was started also to the patients in the control group unconnected with the study because of the ethical causes.

The demographic results of the two groups are seen in table 2. No statistically significant differences were found regarding type of involvement, sex and age ($p > 0.05$).

Pretreatment values of plantar flexor muscle tone, active ankle ROM, CGA, velocity, cadence and stride length in both of the groups are given in tables 3 and 4. There were no statistically significant differences between the two groups regarding these pretreatment data ($p > 0.05$ for all parameters).

While the biofeedback group showed statistically significant improvement regarding tone of plantar flexors and active ROM of ankle ($p < 0.000$ for all parameters), the control group did not display such improvement during the treatment and follow-ups ($p > 0.05$ for all parameters). Comparing 10th day and 1st month evaluations between the two groups, biofeedback group was significantly superior in all measurements ($p < 0.004$ for all measurements) as seen in table 5.

Table 2 The demographic results

	Biofeedback group ($n = 21$)	*Control group* ($n = 11$)	*p*
Age (mean ± SE)	8.90 ± 1.08	8.82 ± 1.46	0.717
Sex	Girl = 8	Girl = 4	0.7731
	Boy = 13	Boy = 7	
Type of involvement	Diplegic = 9	Diplegic = 5	0.8146
	Hemiplegic = 12	Hemiplegic = 6	

CGA, velocity, cadence, stride length values which are given in table 6 demonstrated statistically significant progression in both of the groups ($p < 0.05$ for all parameters). Comparing the above parameters between the groups on the 10th day and 1st month, only cadence did not show a statistically significant differences ($p = 0.350$ and $p = 0.440$, respectively) and all the other parameters were superior ($p < 0.05$) in the favour of the biofeedback group .

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Discussion

In our study, the children who received biofeedback and the exercise programme showed significant improvements regarding muscle tone and active ankle ROM, compared to children who received only the exercise programme did. These results suggest that biofeedback was probably effective in increasing the effectiveness of the exercise programme.

However, Wolf questioned the role of ROM and muscle tone improvements in revealing the efficacy of EMG biofeedback.[16] He asked if a significant increase in active ankle dorsiflexion ROM following feedback training meant that a hemiplegic could walk better. As the correlation between useful function and isolated activity can be uncertain, an area for future research would be to show the effects of biofeedback on functional outcomes. In their meta-analysis, Schleenbaker *et al.*[5] showed that EMG biofeedback improves functional outcomes in patients with hemiplegic stroke. The meta-analysis includes a total sample of 192 cases. It is found that patients receiving EMG biofeedback exhibit increases in upper and lower extremity function above control group significantly. Unfortunately as there is no large sampled controlled study in children with CP, no similar conclusion can be made about the general efficacy of biofeedback for this group. Still results of our study suggest that biofeedback may be

Table 3 Pretreatment values of active ankle ROM and muscle tonus

	Biofeedback group (*n* = 30) *mean ± SE*	*Control group* (*n* = 16) *mean ± SE*	*p*
Muscle tone*	3.00 ± 8.417E-02	3.00 ± 0.13	0.211
Ankle dorsiflexion (knee in flexion)	11.07 ± 0.81	7.40 ± 2.63	0.285
Ankle dorsiflexion (knee in extension)	5.73 ± 1.18	2.00 ± 2.74	0.611

*Given as median ± SE

Table 4 Pretreatment values of CGA, velocity, cadence and stride length

	Biofeedback group (n = 21) mean ± SE	*Control group (n = 11) mean ± SE*	*p*
CGA	37.43 ± 4.41	41.64 ± 6.28	0.633
Velocity (m/sc)	0.60 ± 6.178E-02	0.45 ± 7.961E-02	0.104
Cadence (number of steps/min)	100.90 ± 6.70	102.36 ± 9.37	0.843
Stride length (cm)	32.08 ± 2.95	25.48 ± 3.70	0.159

Table 5 Muscle tone and ROM measurements in the biofeedback and control groups

	Biofeedback group (*n* = 30) *mean ± SE*	*Control group* (*n* = 16) *mean ± SE*	*p****
Muscle tone*			
Pretreatment	3.00 ± 8.417E-02	3.00 ± 0.13	0.211
10th day	1.00 ± 0.11	3.00 ± 0.13	0.000
1st month	1.00 ± 9.398E-02	3.00 ± 0.13	0.000
3rd month	2.00 ± 0.13		
*p***	0.000	0.368	
Ankle dorsiflexion (knee in flexion)			
Pretreatment	11.07 ± 0.81	7.40 ± 2.63	0.285
10th day	19.27 ± 0.97	7.40 ± 2.63	0.004
1st month	19.63 ± 0.93	7.53 ± 2.62	0.000
3rd month	18.37 ± 1.22		
*p***	0.000	0.368	
Ankle dorsiflexion (knee in extension)			
Pretreatment	5.73 ± 1.18	2.00 ± 2.74	0.611
10th day	12.60 ± 0.77	1.87 ± 2.71	0.000
1st month	13.80 ± 0.93	2.13 ± 2.80	0.000
3rd month	11.94 ± 1.39		
*p***	0.000	0.368	

*Given as median ± SE. **Friedman test. ***Mann-Whitney U test.

Table 6 CGA. velocity. cadence and stride length measurements in the biofeedback and control groups

	Biofeedback group (*n* = 21) *mean ± SE*	*Control group* (*n* = 11) *mean ± SE*	*p* (**)
CGA			
Pretreatment	37.43 ± 4.41	41.64 ± 6.28	0.633
10th day	25.19 ± 3.02	40.36 ± 6.13	0.014
1st month	24.80 ± 2.99	37.27 ± 5.91	0.035
3rd month	25.64 ± 3.84		
*p**	0.000	0.000	
Velocity (m/sc)			
Pretreatment	0.60 ± 6.178E-02	0.45 ± 7.961E-02	0.104
10th day	0.73 ± 6.735E-02	0.46 ± 8.384E-02	0.031
1st month	0.75 ± 6.271E-02	0.47 ± 8.367E-02	0.018
3rd month	0.82 ± 8.334E-02		
*p**	0.000	0.003	
Cadence (number of steps/min)			
Pretreatment	100.90 ± 6.70	102.36 ± 9.37	0.843
10th day	110.05 ± 6.94	103.18 ± 9.27	0.350
1st month	111.05 ± 6.43	103.45 ± 9.37	0.440
3rd month	112.28 ± 7.28		
*p**	0.000	0.035	
Stride length (cm)			
Pretreatment	32.08 ± 2.95	25.48 ± 3.70	0.159
10th day	35.78 ± 3.01	25.61 ± 3.74	0.041
1st month	37.21 ± 2.93	26.09 ± 3.74	0.029
3rd month	41.64 ± 3.35		
*p**	0.000	0.004	

* Friedman test. **Mann-Whitney U test.

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useful in children with CP. Although both of the groups improved significantly by means of function, the results of the biofeedback group were superior to the control group. Deficient motor control may be secondary to inadequate inhibition of muscular contraction of antagonists and weakness of agonists. Children augment or inhibit muscle activity more significantly when treated by biofeedback comparing to conventional exercises. Controlling the spasticity and strengthening the key muscles will bring the ability of using the lower extremities in a more functional manner. It can be argued if the gait improvements represent function; however it is clear that gait is not simply isolated activities and it has direct bearing on the ability to use the lower extremities in a functional manner.

Constraint induced movement therapy, which involves intensively training use of the affected limb by repetitive use and shaping procedures, was proven to produce a use-dependent cortical reorganization by neuroimaging and transcranial magnetic studies.[17, 18] According to the system's theory, integration of many systems – including central nervous system – by repetitive practice of functional and goal-directed activities, results in organized and normal movement. In biofeedback therapy, although children might not work on meaningful performance of activities, repetitive and concentrated practice that might be playing a role in brain plasticity is the main principle. In order to understand the mechanisms of recovery obtained by biofeedback treatment, neuroradiological studies investigating cortical reorganization are also needed. These will also help us to improve our knowledge about the neuromuscular treatment approaches.

References

1 Dursun E, Hamamcı N, Dönmez S. Angular biofeedback device for sitting balance of stroke patients. *Stroke* 1996; **27**(8): 1354–1357.
2 Ceceli E, Dursun E, Çakcı A. Comparison of joint-position biofeedback and conventional therapy methods in genu recurvatum after stroke – 6 months' follow-up. *European Journal of Physical Medicine and Rehabilitation* 1996; **6**(5): 141–144.
3 Nichols DS. Balance retraining after stroke using force platform biofeedback. *Physical Therapy* 1997; **77**(5): 553–558.
4 Marcus DA, Scharff L, Mercer S, Turk DC. Nonpharmacological treatment for migraine: incremental utility of physical therapy with relaxation and thermal biofeedback. *Cephalalgia* 1998; **18**(5): 266–272.
5 Schleenbaker RE, Mainous III AG. Electromyographic biofeedback for neuromuscular reeducation in the hemiplegic stroke patient: a meta-analysis. *Archives of Physical Medicine and Rehabilitation* 1993; **74**(12): 1301–1304.
6 Wolf SL, Binder-MacLeod SA. Electromyographic biofeedback applications to hemiplegic patient: changes in upper extremity neuromuscular and functional status. *Physical Therapy* 1983; **63**: 1404–1413.
7 Moreland JD, Thomson MA, Fuoco AR. Electromyographic biofeedback to improve lower extremity function after stroke: a meta-analysis. *Archives of Physical Medicine and Rehabilitation* 1998; **79**(2): 134–140.
8 Dursun N, Dursun E, Kılıç Z. Electromyographic biofeedback-controlled exercise versus conservative care for patellofemoral pain syndrome. *Archives of Physical Medicine and Rehabilitation* 2001; **82**(12): 1692–1695.
9 Crider AB, Glaros AG. A meta-analysis of EMG biofeedback treatment of temporomandibular disorders. *Journal of Orofacial Pain* 1999; **13**(1): 29–37.
10 Krebs DE. Clinical electromyographic feedback following meniscectomy. *Physical Therapy* 1981; **61**(7): 1017–1021.
11 Draper V, Ballard L. Electrical stimulation versus electromyographic biofeedback in the recovery of quadriseps femoris muscle function following anterior cruciate ligament surgery. *Physical Therapy* 1991; **71**(6): 455–461.
12 Nash J, Neilson PD, O'Dwyer NJ. Reducing spasticity to control muscle contracture of children with cerebral palsy. *Developmental Medicine and Child Neurology* 1989; **31**: 471–480.
13 Toner LV, Cook K, Elder GC. Improved ankle function in children with cerebral palsy after computer-assisted motor learning. *Developmental Medicine and Child Neurology* 1998; **40**(12): 829–835.
14 O'Dwyer NJ, Neilson PD, Nash J. Reduction of spasticity in cerebral palsy using feedback of the tonic stretch reflex: A controlled study. *Developmental Medicine and Child Neurology* 1994; **36**: 770–786.
15 Dursun E, Dursun N, Alican D. Ankle-foot orthoses: effect on gait in children with cerebral palsy. *Disability and Rehabilitation* 2002; **24**(7): 345–347
16 Wolf SL. Electromyographic biofeedback applications to stroke patients. *Physical Therapy* 1983; **63**(9): 1448–1459
17 Taub E, Uswatte G, Pidikiti R. Constraint-induced movement therapy: A new family of techniques with broad application to physical rehabilitation – A clinical review. *Journal of Rehabilitation Research and Development* 1999; **36**(3): 237–251.
18 Wolf SL, Blanton S, Baer H, Breshears J, Butler A.Repetitive task practice: A critical review of constraint-induced movement therapy in stroke. *Neurologist* 2002; **8**(6): 325–338.