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CASE REPORT

Electromyographic biofeedback training in a cerebral palsy patient undergoing pronator teres rerouting and brachioradialis to extensor carpi radialis brevis tendon transfer surgery: A case report

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ABSTRACT

Several surgical procedures are used to treat dynamic pronation position of the forearm and flexion deformity of the wrist in cerebral palsy. Postoperative results of pronator teres rerouting were explored, while specially designed postoperative physiotherapy and its outcomes were limited. Herein, we present a case in whom the outcomes of electromyographic biofeedback (EMG-BF) training were assessed after pronator teres rerouting and brachioradialis tendon to extensor carpi radialis brevis tendon transfer combined with derotation osteotomy. The peak value increased, while the resting value decreased for the muscles after the intervention. Range of motion, hand function, manual ability, functional independence, and quality of life levels were improved. In conclusion, EMG biofeedback training may have a positive effect on neuromuscular control of pronator teres and brachioradialis. Free use of the upper extremity and improved manual ability positively affect the activity and quality of life of the patients.

Keywords: Biofeedback, cerebral palsy, electromyographic, pronator rerouting, rehabilitation, tendon transfer.

Several surgical procedures are used to treat dynamic pronation position of the forearm in cerebral palsy (CP) including pronator teres tenotomy, pronator teres release, Green tendon transfer.[1] However, pronator teres rerouting has been shown to be a more effective method.[1-4] Also, flexion deformity of the wrist can be restored by a tendon transfer procedure to augment wrist extension.[1,5,6]

Since the 1970s, several studies have investigated the therapeutic effects of electromyographic biofeedback (EMG-BF) training in CP at different frequencies and duration, even using additional augmented techniques such as virtual reality.[7,8] The positive therapeutic effect of EMG-BF training on motor control, mobility, and manual functioning in CP was reported earlier.[9-12]

Postoperative clinical results of pronator teres rerouting were explored, and postoperative conventional rehabilitation techniques were used in previous studies. However, specially designed physical therapy and its outcomes were limited.[1,3] From this point of view, in this article, we present the outcomes of EMG-BF training conducted after pronator teres rerouting and brachioradialis tendon to extensor carpi radialis brevis (ECRB) tendon transfer combined with derotation osteotomy.

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CASE REPORT

A 15-year-old female patient was diagnosed with right-sided spastic hemiplegic CP due to perinatal hypoxic ischemia and Gross Motor Function Classification System (GMFCS) Level 1. Preoperative pronation deformity was classified according to Tonkin Classification.[13] She had a Grade 4 deformity with no active supination and her forearm position was in 40° of rigid pronation unresponsive to passive manipulation. Due to rigid pronation deformity, osteotomy of the radius was planned.[14] The wrist was in 20° of flexion and there was no deformity of fingers and thumb. The elbow had 25° extension limitation.

Under general anesthesia, a volar forearm approach was performed, the radius shaft was exposed, and the pronator teres was released from the shaft of radius together with its periosteum. Radial shaft osteotomy was performed, and the distal forearm was brought to full the supinated position. The derotated osteotomy line was fixed with a locking plate; six cortices were used in either side of the osteotomy to maintain stability. Pronator teres tendon was rerouted through the interosseous membrane according to Sakellarides technique and sutured to the ulnar side of the empty holes of plate.[15] Brachioradialis tendon was released from radial styloid and surrounding soft tissues through the same incision and transferred subcutaneously to the dorsal side of the distal forearm and with a mini-incision was transferred to ECRB tendon in an end-to-side fashion. The arm was put in a long arm plaster cast for six weeks.

The physical therapy was initiated after plaster cast removal. The sessions were progressed weekly and included active/active-assistive exercises for shoulder, elbow, forearm, wrist and fingers, posture exercises, bandage, retrograde massage, light or moderate activities of daily living and progressive resistive exercises. Exercises was prescribed with written and visual description leaflets. Also, the case was fitted with a short Opponen's splint for night-time use (Figure 1).

In the clinical decision-making process, the EMG-BF training was included in the physical therapy following the postoperative assessments of range of motion (ROM), hand function, and muscular activity. Evidence-based benefits of the EMG-BF on the upper extremity functions of CP patients were mentioned earlier.[7-9,11,12]

The EMG-BF training started in the postoperative eighth week, that is, the second week after plaster cast removal. It was applied twice a week for a total of 12 sessions until the postoperative 14th week.

FIGURE 1. The short Opponens splint.

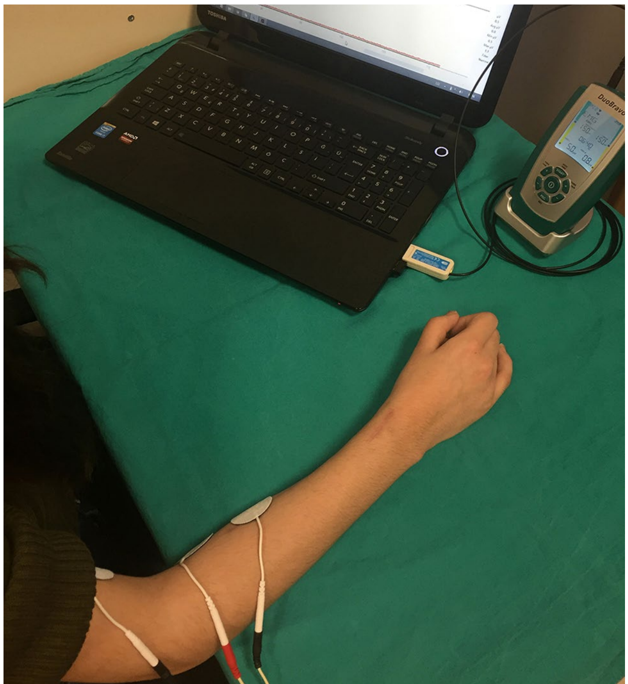

FIGURE 2. EMG-BF setup for m. pronator teres training.
EMG-BF: Electromyographic biofeedback.

The area to be tested was cleaned. Self-adhesive electrodes were used (3 cm in diameter). Due to the less impedance between the skin and electrodes, the bipolar technique was preferred by using double channel (MTR+ Duo Bravo, Berlin, Germany). After the motor points of the muscles (m. brachioradialis, m. pronator teres) were determined, it was positioned 20 mm between the electrode centers on this point.[16] The reference electrode was placed on the biceps muscle. The patient had visual and auditory signals in a quiet room and verbal feedback was provided. The starting position for m. pronator teres training was adduction, 90° elbow flexion, full forearm pronation, neutral wrist and fingers (Figure 2). The starting position for m. brachioradialis training was adduction, 90° elbow flexion, mid-position of the forearm, full flexion of the wrist and neutral fingers (Figure 3). First, resting muscle activity (basal tonus) was recorded for 30 sec. Second, maximum voluntary contraction (MVC) for each muscle was evaluated with 5-sec contraction, 5-sec rest and two repetitions. The training was conducted by adding 2/3 of the mean MVC to the basal tonus. The training was performed 10-sec contraction, 30-sec rest, and 10 repetitions for each muscle separately. The patient was instructed to maintain the muscle activity on the isoelectric line.[17] The patient adhered to all physical therapy, EMG-BF sessions, and home exercises. All therapy sessions and assessments conducted by a single physiotherapist.

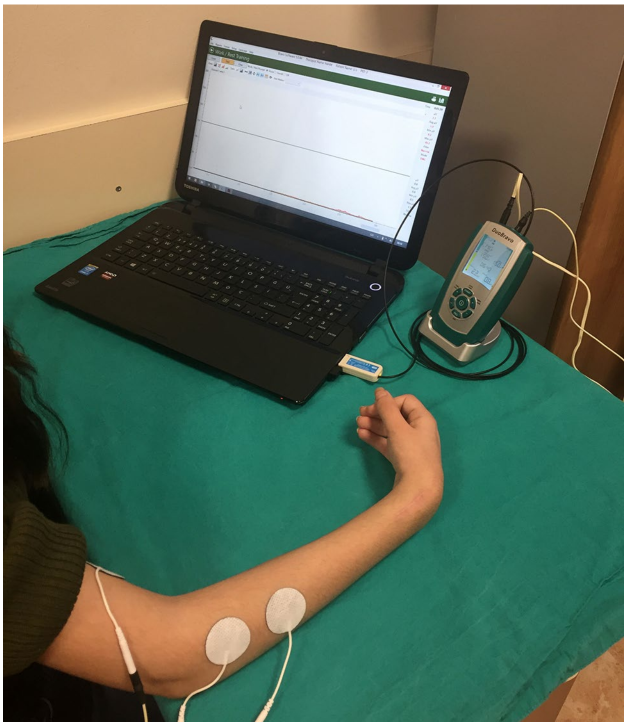

FIGURE 3. EMG-BF setup for m. brachioradialis training.
EMG-BF: Electromyographic biofeedback.

Spasticity, cognitive function, ROM, manual ability, upper extremity performance, and health-related quality of life were assessed in terms of body structure and function, as well as activity and participation. The Modified Ashworth Scale (MAS), Montreal Cognitive Assessment (MoCA), Manual Ability Classification System (MACS), Jebsen Taylor Hand Function Test (JTHFT), Functional Independence Measurement (FIM), and Pediatric Quality of Life Inventory 13-18 years old (PedsQoL) were used. In addition, muscular activities of the transferred muscles were recorded at each session. Preoperative ROM measurements were obtained. Also, all outcome measurements were performed initially (Week 6 following surgery), after the EMG-BF training (Week 14 following surgery), and at six months.

There was no change in the MAS scores before and after the training (MAS=1, both). The MoCA score was 29 points out of 30. Pronation, supination, wrist flexion, extension, radial and ulnar deviation, elbow flexion and extension increased after the training. Besides, full elbow flexion was obtained but 15° elbow extension limitation remained. Compared to non-involved extremity more than 65% of all movements except radial deviation were recovered. At six months of follow up, the patient lost 16° supination and gained 5° wrist and elbow extension. Pre- and postoperative ROM results were given in Table I.

Muscle activity outcomes are shown in Table II for each muscle in testing and training sessions. Peak value increased and resting value decreased for both muscles.

The JTHFT scores for all subtasks relatively improved in each assessment (Table I). The MACS level was changed from III to II after the training. Level II remained the same at six months of follow-up. The FIM score was 122 before and 126 points after the training. The PedsQoL child and parent were improved from 1450 to 1600 and from 1250 to 1525, respectively. The FIM and PedsQoL child-parent scores remained the same at six months of follow-up.

DISCUSSION

The EMG-BF training may be promising on neuromuscular control of pronator teres and brachioradialis. Moreover, it can foster the patient's upper extremity performance and activity participation.[18] The EMG-BF, an important method

TABLE I
Results of ROM and JTHFT

Variables	Preoperative		Before EMG-BF training		After EMG-BF training		6^{th} month follow-up	
	Right	Left	Right	Left	Right	Left	Right	Left
ROM (°)								
Pronation	40	90	(-40)-(-30)	90	58	90	55	90
Supination	-40	90	40-70	90	87	90	71	90
Flexion	20-70	82	45	82	83	82	85	82
Extension	-30	60	-20	60	42	60	47	60
Radial deviation	-20	30	-20	30	7	30	8	30
Ulnar deviation	20	40	20-24	40	35	40	30	40
Elbow flexion	130	150	138	150	154	150	155	150
Elbow extension	-25	0	-21	0	-15	0	-10	0
JTHFT (second)	Could not performed	Could not performed						
Writing			49.74	24.70	63.01	17.57	46.81	16.40
Turning cards			25.69	4.82	17.52	4.84	11.47	5.35
Picking up small objects			64.41	6.99	61.34	6.83	54.32	8.10
Stimulated feeding			Could not performed	11.55	133.16	12.47	92.34	19.06
Stacking checkers			15.64	1.70	15.83	2.93	7.75	4.42
Moving light objects			12.35	5.16	11.57	5.59	9.20	4.90
Moving heavy objects			13.09	5.66	10.07	5.50	19.20	6.20

JTHFT: Jebsen Taylor Hand Function Test; EMG-BF: Electromyographic biofeedback; ROM: Range of motion.

TABLE II
Muscle activity results for each muscle according to EMG-BF sessions

	First testing session	Last testing session	First training session	Last training session
Muscle activity (μV)	Mean±SD	Mean±SD	Mean±SD	Mean±SD
M. Pronator teres				
Work	36.2±4.4	48.6±9.9	36.5±5.0	34.4±8.2
Rest	13.0±2.4	11.0±2.7	16.6±3.1	4.4±1.4
Peak	51.1	93.4	69.6	78.1
Minimum	8.2	4.1	9.0	1.6
M. Brachioradialis				
Work	111.0±12.2	155.3±33.7	91.5±12.3	104.9±26.1
Rest	62.1±13.2	16.9±6.9	59.9±10.9	10.7±4.4
Peak	170.0	241.8	167.7	234.7
Minimum	28.4	5.3	28.4	2.1

EMG-BF: Electromyographic biofeedback; SD: Standard deviation.

that provides behavioral change, contributes to the improvement of the patient's neuromuscular control of the transferred muscles after surgery based on motor learning principles. The patient receives real-time visual and auditory information about her performance, while the transferred muscles are being trained. The EMG-BF affects how well the patient learns the movement, how successfully she performs it, the quality of the movement, her focus and motivation. With frequent and intensive regular practice, it progresses over time, improving function and participating more comfortably in activities of daily living.[7,11,12]

Many studies have reported improvement in ROM after pronator teres rerouting surgery, but our study contributed by including specially designed postoperative physical therapy with EMG-BF training.[2-5,18,19] In our study, the active motion change in forearm supination and wrist extension obtained with EMG-BF was higher than the case series reported in the literature.[1-4] In our study, the active motion change obtained after tendon transfer surgery exceeded the results of other studies when the change obtained after EMG-BF training was added. Physiotherapy has not gone beyond universal therapy (active, passive and resistive exercise) in studies after upper extremity tendon transfer in CP.[1-3] Therefore, the superiority of surgery over botulinum toxin and therapy has been reported.[1] However, it has been shown in this study that physical therapy with EMG-BF may contribute to the improvement of the patient. Also, it is striking that the change in ROM measurements continues to increase in all joints after EMG-BF. On the other hand, since a decrease in supination was detected at six months of follow-up, the risk of joint motion loss in long-term follow-up should be considered in future studies.

Although the primary goal was to increase the muscle activity of the transferred muscles in EMG-BF, it also resulted in a decrease in basal tone for each muscle. We attribute this to the patient's learning and facilitation her neuromuscular control.[7,8]

A decrease for independence in self-care and participation was reported in CP.[20] Evidence for the contribution of surgical techniques to activity and participation indicators is weak in a systematic review.[21] We observed an improvement in hand and upper extremity performance and activity participation with shortened time spent for all subtasks in JTHFT and progressed MACS level. Stimulated feeding task could not be performed by the patient before training, but later the task was performed. This development was preserved up to six months with the use of the upper extremity in daily manual tasks. In this report, EMG-BF was utilized as a useful method to increase free use of the upper extremity and to allow muscle tone regulation. The patient who already had a high level of independence became more independent. This result showed increased self-sufficiency in daily life performance, in line with the results obtained in JTHFT, an activities of daily living simulation. Despite a study that did not report differences in PedQoL scores,[1] there was an improvement in the quality of life of our patient and her caregiver in the early follow-up.

The only limitation to this report is the lack of preoperative muscle activity measurements. Nevertheless, the contribution of EMG-BF is clear compared to pre- and postoperative ROM measurements and active motion change. In addition, the use of general upper extremity scales is notable in the literature.[4] The second strength of this report is the inclusion of outcome measures developed specific to CP while assessing the current and ongoing functional level of the upper extremity identified in the core sets.[1]

Patient Perspective: "I was not able to use my hand in anyway. For instance, I was not able to crack the egg. I had trouble holding the tray and eating meals. Now, I can do everything. I can even hold a large glass full of water and use a fork. This treatment provides benefit to have greater motion capability."

In conclusion, this report showed valuable outcomes for the patient with CP who underwent pronator rerouting and brachioradialis to ECRB tendon transfer surgery combined with derotation osteotomy. Tonus regulation, the use of an audio-visual agent with appropriate technique, reinforced voluntary effort and muscular awareness, active participation and motivation with supervised, regular, and prescribed follow-up enabled benefits to the patient's postoperative outcomes. In parallel with the techniques developed in upper limb surgery in CP, further studies that investigate postoperative physical therapy and EMG-BF efficiency are warranted.

Patient Consent for Publication: A written informed consent was obtained from the parent of the patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, design, literature review, data collection and/or pro-cessing: H.U.Ö.; Control/supervision, critical review: A.K., A.F.D.; Analysis and/or interpretation, writing the article, references and fundings, materials, other: H.U.Ö., A.K., A.F.D.

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