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# Effect of EMG biofeedback to improve upper extremity in children with cerebral palsy: A randomized controlled trail

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**Background** : *Cerebral palsy has pathology in immature brain problem; ischemic brain, and hypoxic brain. The cause of the pathology can be prenatal, perinatal and postnatal. EMG biofeedback is a muscles training program using electrical stimulation modality to train specific weakness of the muscles or pathologic side. Feedback response to the patients by visual or evidence supporting sound can assist the patients to train themselves specifically. However, there are few evidences that support the efficacy of electromyographic (EMG) biofeedback in training of muscles in cerebral palsy.*

**Objective** : *To study the effect of electromyographic biofeedback on upper extremities to improve hand function in children with cerebral palsy.*

**Methods** : *Forty children with cerebral palsy who have impairment of the upper extremity and hand functions. The children were randomly assigned into two groups. Biofeedback group consisted of 20 patients that each received EMG biofeedback training of 3 muscles for 30 minutes plus three-task training for 30 minutes. The conventional group consisted of 20 patients that received three-task training for 60 minutes. The upper extremity and hand functions were evaluated before starting the training, and then at 4 weeks and 8 weeks.*

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**Results** : *Biofeedback group displayed statistically significant improvement regarding 3 subtests of Jebsen hand function test (JHFT) (P = 0.004, P = 0.017, P = 0.004). Comparing with before starting training, mean decreasing of time spending at 4th week were 15.03 ± 4.01, 232.42 ± 74.52 and 14.24 ± 3.80, and at 8th week were 13.32 ± 2.70, 251.85 ± 80.25 and 10.34 ± 3.28. Conventional group displayed statistically significant improvement regarding 1 subtest of JHFT (P = 0.006). Comparing with before starting training, the mean decreased of time spent at 4th week were 174.90 ± 49.20. Biofeedback group showed statistically significant progress over the conventional group in 1 subtest of JHFT (P = 0.002, P = 0.005).*

**Conclusion** : *Effect of EMG biofeedback on upper extremity and hand functions in children with cerebral palsy especially in large muscles trained by EMG biofeedback is superior to the conventional therapy.*

**Keywords** : *Electromyographic biofeedback, Jabson hand function test, cerebral palsy.*

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**รัตนา รัตนาธาร. ผลของการฝึกการทำงานของแขนและมือในเด็กสมองพิการด้วยเครื่องกระตุ้นกล้ามเนื้อเพื่อการเรียนรู้: การทดสอบแบบสุ่มมีกลุ่มควบคุม. จุฬาลงกรณ์เวชสาร 2560 ก.ค. – ส.ค.; 61(4): 451 – 63**

**เหตุผลของการทำวิจัย** : *เด็กสมองพิการเป็นผู้ป่วยที่มีปัญหาทางสมอง โดยพยาธิสภาพเกิดจากสมองขาดเลือดและออกซิเจน ได้มีการใช้เครื่องกระตุ้นกล้ามเนื้อเพื่อการเรียนรู้ (electromyographic (EMG) biofeedback) ในการพัฒนาความแข็งแรงและการทำงานของกล้ามเนื้อแขนและมือ ได้มีทำการศึกษาการใช้เครื่องกระตุ้นกล้ามเนื้อเพื่อการเรียนรู้ (EMG biofeedback) ในการฝึกและพัฒนาการทำงานของกล้ามเนื้อในหลายกลุ่มโรคทางสมอง รวมทั้งในกลุ่มโรคเด็กสมองพิการ แต่ที่ผ่านมามีการศึกษาการใช้เครื่องกระตุ้นกล้ามเนื้อเพื่อการเรียนรู้ (EMG biofeedback) ในกล้ามเนื้อแขนและมือจำนวนน้อยมาก*

**วัตถุประสงค์** : *เพื่อศึกษาผลของการฝึกการทำงานของแขนและมือในเด็กสมองพิการด้วยเครื่อง กระตุ้นกล้ามเนื้อเพื่อการเรียนรู้*

**วิธีการทำวิจัย** : *ผู้ป่วยเด็กสมองพิการที่มีความผิดปกติของแขนและมือจำนวน 40 ราย แบ่งผู้ป่วยด้วยวิธีสุ่มออกเป็น 2 กลุ่ม กลุ่ม biofeedback จำนวน 20 ราย ได้รับการฝึกการทำงานของแขนและมือโดยใช้เครื่อง EMG biofeedback ที่กล้ามเนื้อ 3 มัด รวม 30 นาที และฝึกทำ 3 กิจกรรม อีก 30 นาที กลุ่มการฝึกแบบดั้งเดิมได้รับการฝึกทำ 3 กิจกรรม รวม 60 นาที ประเมินการทำงานของแขนและมือก่อนและหลังการฝึกที่ 4 และ 8 สัปดาห์*

**ผลการศึกษา** : *ผู้ป่วยกลุ่ม biofeedback ใช้เวลาในการทำทดสอบลดลงใน 3 กลุ่มทดสอบย่อยของ Jebsen hand function test (JHFT) อย่างมีนัยสำคัญทางสถิติ ($P < 0.0001$) โดยค่าเฉลี่ยของเวลาที่ลดลงเมื่อเทียบที่ 4 สัปดาห์กับก่อนฝึกเท่ากับ $15.03 \pm 4.01$, $14.24 \pm 3.80$ และ $232.42 \pm 74.52$ และเมื่อเทียบที่ 8 สัปดาห์กับก่อนฝึกเท่ากับ $13.32 \pm 2.70$, $10.34 \pm 3.28$ และ $251.85 \pm 80.25$ ผู้ป่วยกลุ่มฝึกแบบดั้งเดิมใช้เวลาในการทดสอบลดลงใน 1 กลุ่มย่อยของ JHFT อย่างมีนัยสำคัญทางสถิติ ($P < 0.0001$) โดยค่าเฉลี่ยของเวลาที่ลดลงเมื่อเทียบที่ 4 สัปดาห์กับก่อนฝึกเท่ากับ $174.90 \pm 49.20$ กลุ่ม biofeedback มีค่าเฉลี่ยผลต่างของเวลาเมื่อเทียบที่ 4 และ 8 สัปดาห์กับก่อนฝึกใน 1 กลุ่มย่อยของ JHFT ($P = 0.02$ )*

**สรุป** : *ผลของเครื่องกระตุ้นกล้ามเนื้อเพื่อการเรียนรู้ในการทำงานของแขนและมือในเด็กสมองพิการเหนือกว่าการฝึกแบบดั้งเดิมอย่างมีนัยสำคัญทางสถิติ*

**คำสำคัญ** : *Electromyographic biofeedback, Jabson hand function test, การทำงานของแขนและมือ, เด็กสมองพิการ.*

Cerebral palsy has pathology in immature brain problems. The pathology is caused by prenatal, perinatal and postnatal.[1 - 3] Most of the patients suffer from various problems, i.e., movement disorder, poor physical performance, development, perception, communication, behavior and also musculoskeletal problems.[4] Most common problems ( > 50 percents) are weakness and spasticity in both upper and lower extremities that can affect to soft tissue around the joints that show bone growth and development, in return causing cerebral palsy children more impairment and disability.[5] In present studies, there are many techniques and treatment to improve function in cerebral palsy children [6] such as: neurodevelopmental therapy (NDT), hand-arm bimanual intensive training (HABIT) to improve both hands function, normal and pathological side, constraint-induced movement therapy (CIMT) to improve pathological side and limit function of normal side, electromyographic (EMG) biofeedback, botulinum toxin A injection into spastic muscles. However, there are few studies about upper extremities in cerebral palsy children. So far, there have been no definite study to improve hand function of cerebral palsy patients.[7]

EMG biofeedback is muscles training by using electrical stimulation modality to train specific weakness muscles or pathologic side. Feedback response to the patients by visual or evidence supporting sound can make the patients to train themselves specifically, on the one hand. The patients can learn how to adapt and practice themselves to achieve their goals to improve their function, motor power and decrease spasticity.[8] The patient can learn to move their specific muscles to improve their function by decreasing spasticity and increasing muscles relaxation.[9] There are many studies about the effect of EMG biofeedback in the patients who have weakness and spasticity in upper extremities [10 - 13] and lower extremities[14 – 16] in many groups of patients such as stroke[17,18], traumatic brain injury, spinal cord injury patients.[19]

In 1983 Wolf SL, Binder-MacLeod SA**.** studied about the effectiveness of EMG biofeedback in 31 hemiparesis; 22 patients using EMG biofeedback had more significantly statistic improvement in motor power range of motion and decreasing spasticity and also upper extremities hand function than 9 control patients.[11] In 1989 Crow JL, *et al*. studied the effectiveness of EMG biofeedback to improve the upper extremities function in stroke patients. There are statistically significant EMG biofeedback training group improve upper extremities and hand function score.[13] In 1998 Moreland JD, *et al*. studies concluded 12 meta-analysis of EMG biofeedback training studies and/or with or without conventional therapy (randomized controlled trials) to measure lower extremities function, improvement of motor power (strength and endurance, range of motion). Results showed that EMG biofeedback group significantly improved strength of ankle dorsiflex muscles' strength when compared with the conventional group.[20] In 1998Toner LV, *et al* studied EMG biofeedback treatment in 5 cerebral palsy children and a case of tip toe walking; there was significantly improvement both in strength of muscles and the active range of motion of joints.[22]

In 2003 Armagan O, *et al*. studied EMG biofeedbacktreatment of hand muscles weakness in 27 hemi-paresis stroke patients. EMG biofeedback group had statistically significant improvement in

range of motion of wrist joint and also strength of wirst extensor and finger extensor muscles group when compared with placebo EMG biofeedback.[21] In 2004 Erbil D, et al studied 36 cerebral palsy patients; 21 cases for gait training by using EMG biofeedback and 15 cases with conventional physical therapy. The study showed significantly more improvement in muscle strength of ankle plantar flexion muscles, range of motion and also gait pattern in EMG biofeedback groups than conventional group.[23] Conclusion Rehabilitation by EMG biofeedback statistically significant improves effectiveness of musculoskeletal system e.g. range of motion and strength of muscles. EMG Biofeedback can improve the effectiveness of outcome of treatment in cerebral palsy children and also safety for the children. The children have limitation of intention to cooperate tasks or activities especially cerebral palsy children therefore EMG biofeedback stimulation is one quite interesting technique to precipitate the children to success more activities.

This study is design to evaluate the effectiveness of EMG biofeedback to upper extremities and hand function of cerebral palsy compare with conventional therapy.

## Methods

### Type of Study

Participants: Cerebral palsy children 5 - 14 years old; Inclusion criteria reference by HABIT study who can do wrist extension more than 20 degrees and metacarpopharyngeal joint extension more than 10 degress from full finger flexion, Lifting arm from the table more than 6 inches. Intelligence quotient (Raven's progressive matrices) is more than 70. Exclusion criteria was others healthy problems, in adequate treatment and/or uncontrolled seizure or epilepsy, vision problems, spasticity (Modified Ashworth score > 3), previous surgery in pathological upper extremity or hand within a year, botulinum toxin therapy in pathological upper extremity within 6 months or during study period or deny to continue .

Sample size calculations: Calculated from Gordon AM, *et al*. study [24] by using two independent group CI = 95 %, power 90% and drop out 20 percent. Calculated number is 19 cases per group. Total is 38 cases.

Study designs: single-blind, controlled trial, block of 4 randomization was divided into 2 groups: first was EMG biofeedback and second group was conventional group.

Group I EMG biofeedback : The patients were trained by EMG biofeedback Delsys Myomonitor IV. The surface electrode was put at the movement muscles of upper extremities and hands muscles by the same occupational therapist. First surface electrodes were applied at finger extensors for 10 minutes; Second surface electrodes were applied at wrist extensors for 10 minutes; Third surface electrode applied at the Triceps for 10 minutes. The patients had to do three tasks, first was painting, second throwing the ball in the basket and third putting red bean into the cup by a spoon. The patients had to do every task of ; 10 minutes each. Total time was 60 minutes per day for 3 days per week for 4 weeks.

Group II Conventional therapy: These group of patients had to do three tasks consist of painting, throwing

the ball into the basket and putting red bean in to a cup by a spoon. The patients had to do every task; 20 minutes per task. Total time was 60 minutes per day for 3 days per week for 4 weeks. Both groups were trained by an expert occupational therapist.

All patients had to be examined by single blinded evaluator. Age, sex, upper extremity lesion side, history of healthy condition, epilepsy or seizure treatment, vision problems, history of surgery in one year and/or history of botulinum toxin A injection at the upper extremity lesion side in 6 months. And also the patients were evaluated by intelligent test, i.e., Raven's progressive matrices by a psychologist. They were evaluated pre-training and post training at 4 and 8 weeks.

**Outcome measurement:** Jebsen-Taylor test hand function (JHFT) was the hand function test. For this study we chosed 6 from 7 evaluation score tests: card turning, picking up small common objects (pennies, paper clips bottle caps), stimulated feedings (putting red bean by spoon), stacking checkers, moving light objects (empty cans), moving heavy objects (1 pound weight cans). Subtest score was the time (seconds) to complete task. Total score needed some time for each subtest.

**Statistical analysis**

Data was analyzed by SPSS (cities version 15.0). Data analysis was blinded. Basic data was analyzed to compared between the two groups. Age analyzed by independent *t*-test, sex, classification of cerebral palsy, trainable pathologic side anal Chi-square test. Analyzed pre and post training by Repeated measured ANOVA with post-hoc analysis. Anlayzed treatment outcome compared between two groups by mean differences and Mann-Whitney U test.

**Results**

Basic data showed both biofeedback and conventional groups had average age 10.5 year old and 9.3 years old. Both groups had equal male and female. Trainable weakness upper extremities and hand side was left side more than right side in both groups. In both groups were most cerebral palsy diplegia. There was no significant difference in basic data between both groups (Table 1).

From 51 cerebral palsy cases, there was 40 cases in include criteria in this study. Forty cases were devided into two groups and all cases could succeed and finish the research without any drop out (Figure 1).

Biofeedback group success to do Jebsen hand function test (JHFT) for three subgroups item; card turning, stimulated feedings (putting red bean by spoon) and moving heavy objects by taking time statistically less than conventional group.(at week $4^{th}$ $P = 0.004$, $P = 0.017$, $P = 0.004$ and at week $8^{th}$ $P < 0.001$, $P = 0.016$, $P = 0.016$) (Table 2, 3).

Conventional group was successful to do Jebsen hand function test (JHFT) for only one subgroup item ; stimulated feedings (putting red bean by spoon statistically decrease less time.(at week $4^{th}$ $P = 0.006$, and at week $8^{th}$ $P = 0.014$) (Table 2, 3). Biofeedback group has significant statistically less time to do tasks at week $4^{th}$ and week $8^{th}$ when compared pre training and post training in one subgroup item; moving heavy subject and significant statistically better than conventional group ($P = 0.002$ and $P = 0.005$)(Table 3).

**Table 1.** Basic data of participants.

| Characteristics | Biofeedback (20) Mean ± SE | Conventional (20) Mean ± SE | *P* - value |
|---|---|---|---|
| Age | 10.500 ± 2.351 | 9.300 ± 2.536 | 0.738* |
| Gender (female/male) | 10/10 | 10/10 | 1.000 |
| Trained side (right/left) | 7/13 | 9/11 | 0.748 |
| Type | | | 0.139 |
| Spastic diplegia | 15 | 18 | |
| Spastic quadriplegia | 5 | 1 | |
| Spastic hemiplegia | 0 | 1 | |

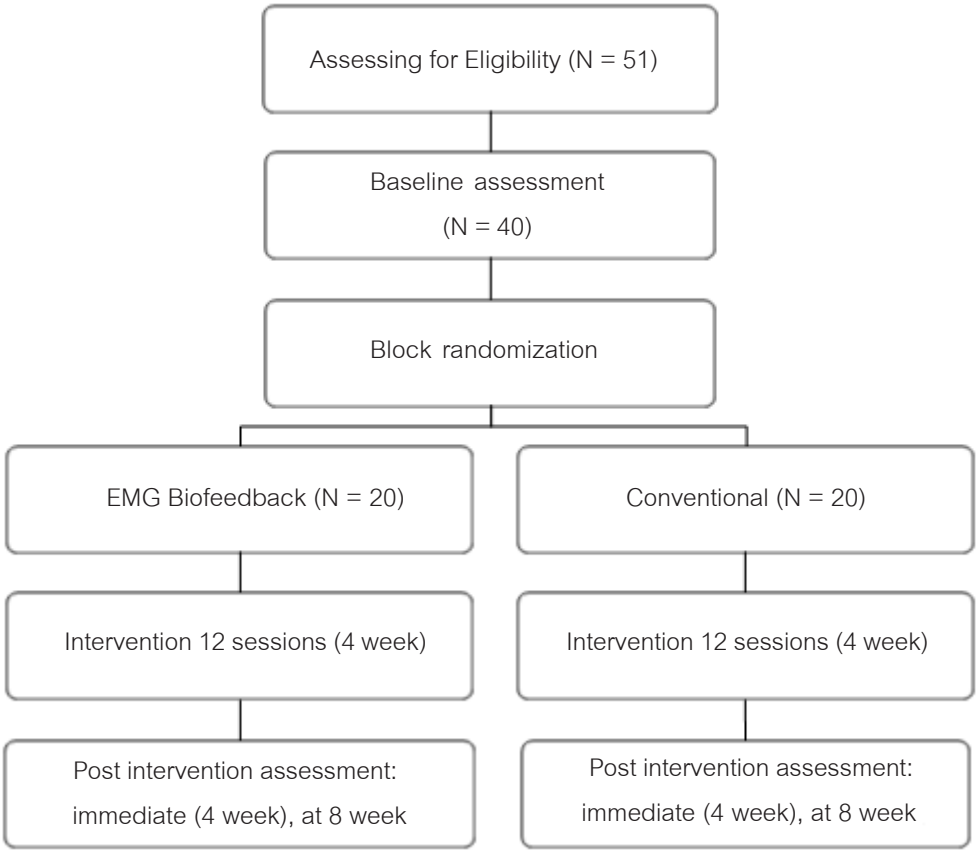


**Figure 1.** Flow chart of participants in the study.

**Table 2.** Average duration time of JHFT pre and post training at week 4th and 8th and mean difference between two groups.

| **Measures** | | **Intervention Biofeedback** | **Conventional** | **Mean difference between group *P*-value** |
|---|---|---|---|---|
| JHFT - Page turning | Pretest (I) | 35.61 ± 5.99 | 48.82 ± 14.99 | 0.0008 |
| | At 4 week (II) | 20.57 ± 2.57 | 33.21 ± 8.61 | 0.0001 |
| | At 8 week(III) | 22.29 ± 4.08 | 30.36 ± 6.36 | 0.0001 |
| | I-II (diff.) | 15.04 ± 4.01 | 15.61 ± 6.69 | 0.267 |
| | I-III (diff.) | 13.32 ± 2.70 | 18.45 ± 9.15 | 0.279 |
| | *P*-value I-II (diff.) | 0.004 * | 0.092 | |
| | *P*-value I-III (diff.) | <0.001 * | 0.174 | |
| JHFT – Lifting small object | Pretest (I) | 142.56 ± 60.22 | 129.14 ± 60.30 | 0.4856 |
| | At 4 week (II) | 89.77 ± 46.23 | 87.18 ± 38.54 | 0.8484 |
| | At 8 week (III) | 89.19 ± 38.82 | 95.56 ± 46.22 | 0.6397 |
| | I-II (diff.) | 52.80 ± 29.61 | 41.95 ± 28.49 | 0.088 |
| | I-III (diff.) | 53.37 ± 25.47 | 33.58 ± 27.95 | 0.066 |
| | *P*-value I-II (diff.) | 0.272 | 0.472 | |
| | *P*-value I-III (diff.) | 0.149 | 0.733 | |
| JHFT – Simulate feeding | Pretest (I) | 342.70 ± 85.60 | 486.11 ± 78.44 | 0.0001 |
| | At 4 week (II) | 110.28 ± 23.78 | 311.21 ± 66.14 | 0.0001 |
| | At 8 week (III) | 90.85 ± 21.26 | 315.04 ± 71.42 | 0.0001 |
| | I-II (diff.) | 232.42 ± 74.52 | 174.90 ± 49.20 | 0.892 |
| | I-III (diff.) | 251.85 ± 80.25 | 171.07 ± 53.33 | 0.626 |
| | *P*-value I-II (diff.) | 0.017* | 0.006 * | |
| | *P*-value I-III (diff.) | 0.016 * | 0.014* | |

Mann-Whitney U test for between group analysis; *P* value < 0.05 indicates is significant difference.*Repeated measure ANOVA with post-hoc analysis for within group analysis; JHFT= Jebsen Hand Function Test, diff.=difference

**Table 3.** Average duration time of JHFT of pre and post training at week 4th and 8th and mean difference between two groups.

| Measures | | Intervention Biofeedback | Conventional | Mean difference between group *P*-value |
|---|---|---|---|---|
| JHFT – Checkers | Pretest (I) | 56.72 ± 23.35 | 63.76 ± 20.12 | 0.3135 |
| | At 4 week (II) | 41.97 ± 22.49 | 46.25 ± 12.05 | 0.4578 |
| | At 8 week (III) | 41.73 ± 22.56 | 55.53 ± 16.99 | 0.0351 |
| | I-II (diff.) | 14.75 ± 6.10 | 17.51 ± 17.10 | 0.027 |
| | I-III (diff.) | 14.99 ± 8.28 | 7.73 ± 16.63 | 0.298 |
| | *P*-value I-II (diff.) | 0.272 | 0.472 | |
| | *P*-value I-III (diff.) | 0.149 | 0.733 | |
| JHFT – Large, light object | Pretest (I) | 34.57 ± 6.69 | 46.75 ± 13.48 | 0.0009 |
| | At 4 week (II) | 20.34 ± 3.57 | 37.32 ± 10.78 | 0.0001 |
| | At 8 week (III) | 24.23 ± 4.16 | 34.43 ± 9.63 | 0.0001 |
| | I-II (diff.) | 14.24 ± 3.80 | 9.43 ± 7.90 | 0.105 |
| | I-III (diff.) | 10.34 ± 3.28 | 12.32 ± 8.70 | 0.330 |
| | *P*-value I-II (diff.) | 0.004* | 0.742 | |
| | *P*-value I-III (diff.) | 0.016* | 0.519 | |
| JHFT – Large, heavy object | Pretest (I) | 168.54 ± 71.90 | 106.88 ± 40.35 | 0.0019 |
| | At 4 week (II) | 78.78 ± 44.80 | 70.72 ± 30.73 | 0.5110 |
| | At 8 week(III) | 72.30 ± 41.48 | 52.96 ± 23.54 | 0.0777 |
| | I-II (diff.) | 89.76 ± 52.20 | 36.16 ± 23.23 | 0.002 |
| | I-III (diff.) | 96.24 ± 52.16 | 53.87 ± 26.91 | 0.005 |
| | *P*-value I-II (diff.) | 0.305 | 0.408 | |
| | *P*-value I-III (diff.) | 0.242 | 0.179 | |

Mann-Whitney U test for between group analysis; *P* value < 0.05 indicates is significant difference.*Repeated measure ANOVA with post-hoc analysis for within group analysis; JHFT= Jebsen Hand Function Test, diff.=difference

## Discussion

From other previous studies, in 1998 Toner LV, *et al.* studied the effectiveness of EMG biofeedback in cerebral palsy and concluded that biofeedback machine statistically significant help to increase degree of active range of motion of joints and also increase ankle dorsiflexion muscles group.[22]

In 2004 Erbil D, *et al.* studied the effectiveness of EMG biofeedback statistically significantly improved the strength of ankle plantar flexion group, degree of active range of motion of ankle joint and develop gait pattern better than convention group. In 2010 Rosemary B. studied that biofeedback help to improve upper extremities function. [26]

Form this study, EMG biofeedback group statistically significantly decreased duration of success in spending time of 3 subgroups tasks of hand function test (JTHF). As for conventional group that had three tasks specific activities. There was statistically significantly decreasing of one specific task activity of subgroup of hand function test.

Biofeedback technique was the muscle training control to specific task activities of upper extremities and hand muscles training. This technique stimulated more neuroplasticity mechanism. When compared between two groups studies, biofeedback group statistically significantly decreased the duration of time spent to success in one subgroup of hand function test by training large muscles by biofeedback technique to increase the range of motion of elbow flexion and extension and decrease spasticity.

In this present, there is developing biofeedback technique to do neurological and musculoskeletal system for rehabilitation and also more advance in the future .[25] Task-oriented biofeedback therapy is new technology to develop real situation and environment to train the patient more effectiveness and reality but this technology is more expensive and inadequate research.

From this study shows that biofeedback muscle training of upper extremities and hand muscles in cerebral palsy patients have more successful work and function superior to conventional group therapy. Our objective from this study is to stimulate cerebral palsy children to improve their upper extremities and hand function to be more independent, and do more activities of daily living or more advanced hand function activities with minimal assistance or without any assistance. The benefit from this study, physician, physical therapist and occupational therapist can use this technique to rehab cerebral palsy patient with safety and not at high cost. We have plan to do more specific biofeedback muscles training to do more specific tasks for cerebral palsy patient function improvement.

## Conclusion

EMG biofeedback in the upper extremities and hand functions training in cerebral palsy has statistically significant improvement of upper extremities and hand function superior to conventional group. We can conclude that biofeedback muscles training technique is one of the great technique to train cerebral palsy children in order to improve and develop their upper extremities and hand functions to achieve their independent activities with low cost technology.

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