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The Effects of Functional Electrical Stimulation on Forced Vital Capacity and Phonation Capabilities in Children with Spastic Cerebral Palsy

The purpose of this study is to see the effect of functional electrical stimulation on forced vital capacity and alternating motion rate in children with spastic cerebral palsy. This study divided 20 children with spastic cerebral palsy into two groups; functional electrical stimulation treatment group and control group. Functional electrical stimulation treatment group had 20min per day treatment three times a week for four weeks and the control group did not have any treatment. Before and after intervention, this study measured forced vital capacity and alternate motion rate(/peo/,/teo/) for all children. Forced vital capacity showed statistically significant increase for the group with functional electrical stimulation(p<.05) while the control group did not show any significant increase(p>.05). Alternate motion rate showed statistically significant increase for the group with functional electrical stimulation(p<.05) while the control group did not show any significant increase(p>.05). This result shows that functional electrical stimulation affected the ability of the children with spastic cerebral palsy who have decreased breathing and phonation capability.

Key words: *Cerebral Palsy; FES; Forced Vital Capacity(FVC); Phonation Capability*

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INTRODUCTION

The definition of cerebral palsy is a general term for illness of motor nerve group originated from the central nerve. When American Academy for Cerebral Palsy was established in 1947, cerebral palsy was widely accepted by its specialists and this academy is now known as The American Academy for Cerebral Palsy & Development Medicine. Bobath society defined cerebral palsy as a clinical syndrome with brain's functional disability due to immature brain's non-progressive lesion or deficit and it is occurred by many different reasons.

There are many different causes for it. Prenatal causes such as hypoxia in uterus and fetus decreased blood flow take up about 30% of total causes. At the time of birth, placenta previa and umbilical cord pressure cause suffocation which take up about 60%. After birth causes are brain damage and cerebrovascular accident which take up about 10%. Cerebral palsy ratio is as follows; bilateral spastic cerebral palsy is the most common cerebral palsy which happens 1.2 persons out of 1,000 new born babies(0.5 out of 1,000 normal new born babies, 10 out of 1,000 low birth weight, and 40 to 50 out of 1,000 extremely low birth weight). Unilateral spastic cerebral palsy occurs 0.6 out of 1,000 new born babies(1). Spastic in bilateral spastic cerebral palsy means that when muscle is stretched passively, muscle's tension increases as a stretch reflex increases. This spasticity causes excessive stiffness and tension in muscle as a result of damage in brain's sensory motor cortex to white matter projection as well as motor cortex (2). Moreover, upper motor neuron damage symptoms such as consistent abnormal primitive reflex, cross over of hip adductor appear distinctly. It also causes loss of control ability between coactivation and reciprocal inhibition, difficulties at the beginning of specific muscle group(hip extensor, triceps muscle of arm), maintaining(thoracic vertebrae extensor), and maintaining the last step(hip flexor, adductor, and internal rotator), and reduces balancing ability of flexor and extensor which in turn causing reduced range of motion(3).

Cerebral palsy is a complex disability that accompanies various disabilities. It shows abnormal postural reflex and muscle stiffness as well as auditory, vision, tactile, sense of equilibrium, and cognitive ability(4). Spastic cerebral palsy causes frequent joint deformation because it has couple of abnormal postures. It appears as kyphosis, chest bulging, deformation of hip and knee joint, and dislocation of hip joint. These postures cause a big trouble in activation of respiratory muscles and disturb balanced normal muscle tension interrupting normal breathing. This breathing causes inverse breathing when air breathing is forced and chest and the last five ribs are forced down. This curves the body and makes it more difficult to breathe. Consequently, it causes chest deformation and scoliosis(5). The above result leads to motor disturbance in breathing, vocalization, and articulating organs. There are many therapeutic exercises such as diaphragmatic respiration, rib expansion method, and pursed lips breathing for cerebral palsy children with breathing disabilities.

However, there are not enough functional electrical stimulation methods such as strengthening weakened muscle by stimulating motor fiber to contract muscle, reducing stiffness, or increasing range of motion. Therefore, this study looks into the effect of functional electrical stimulation on forced vital capacity and alternating motion rate(AMR) calculated by repeating one syllable.

MATERIALS AND METHODS

Subjects

This study selected 20 teenagers diagnosed as spastic cerebral palsy living in Daegu. They were divided into two groups. 10 children were in a treatment group with functional electrical stimulation treatment and the other 10 children were in a control group. They are all able to understand what therapists order and able to sit up with unstable posture. Average age of the treatment group was 15.41 with average height of 153cm and average weight of 49.01kg. Average age of the control group was 16.01 with average height of 157cm and average weight of 50.51kg.

Procedure and Measurement

The treatment subject lies on a treatment mat and bend knees. Surface electrodes are attached to abdominal muscle. Electrode is attached right below each costal margin and near pubis close to the median line to stimulate rectus abdominis muscle. Then, the stimulation with frequency of 45Hz and strength of 35-60mA/5㎠ was given for 20 minutes a day, three times a week for four weeks. Forced vital capacity(FVC) was measured using the speed of maximum air discharge by CardioTouch 3000(Bionet, Korea). Posture was to align head and trunk while seated with 90 degrees bent hip and knee joint. In this posture, alternating motion rate(AMR) was measured for the sound /peo/ and /teo/.

Data Analysis

The data analysis was conducted on the total of 20 subjects; the treatment group of 10 with functional electrical stimulation and the control group of 10 with no treatment. To verify the effect of functional electrical stimulation, this study conducted independent sample t-test. SPSS 12.0 for Window was used to analyze and verify data at significant level of .05.

RESULTS

Forced Vital Capacity Comparison between the Treatment and the Control Group

For the treatment group, forced vital capacity before the treatment was 1928.50㎖ and it increased to 2183.70㎖ after four weeks. For the control group, it changed from 1968.00㎖ to 2007.00㎖. Independent sample t-test indicated there was no significant difference before the test. However, the difference was significant after the treatment($p<.05$)(Table 1)(Fig. 1).

Table 1. Maximal expiratory flow rate comparison between the treatment group and control group before and after the treatment

(㎖)

	Group	M±SD	t	p
Before	Treatment group	1928.50±55.37	-.695	.49
	Control group	1968.00±170.99		
After	Treatment group	2183.70±101.78	2.986	.01*
	Control group	2007.00±157.05		

*p<.01

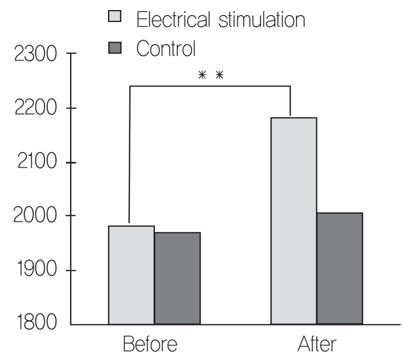

Fig. 1. Maximal expiratory flow rate comparison between the treatment group and control group before and after the treatment

Change in /peo/ between the Treatment and Control Group

Pronunciation /peo/ for the treatment group was 4.29sec before the treatment and 3.44sec after four weeks of treatment. For control group, it was 3.95sec and changed to 3.96sec in four weeks. Independent sample t-test showed that there was no significant difference between the two groups. However, there was significant difference after the treatment($p<.05$) (Table 2)(Fig. 2).

Table 2. Alternating motion rate(AMR) comparison of pronunciation /peo/ between the treatment and control group before and after the treatment

(sec)

Group		M±SD	t	p
Before	Treatment group	4.29±.581	1.30	.21
	Control group	3.95±.559		
After	Treatment group	3.44±.357	-2.48	.03*
	Control group	3.96±.577		

*p<.05

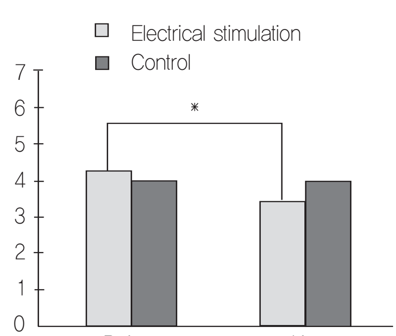

Fig. 2. Pronunciation /peo/ comparison between the treatment and control group before and after the treatment

Change in /teo/ between the Treatment and Control Group

Pronunciation /peo/ for the treatment group was 4.90sec before the treatment and 3.87sec after four weeks of treatment. For control group, it was 4.69sec and changed to 4.67sec in four weeks. Independent sample t-test showed that there was no significant difference between the two groups. However, there was significant difference after the treatment($p<.05$)(Table 3)(Fig. 3).

Table 3. Pronunciation /teo/ comparison between the treatment and control group before and after the treatment

(sec)

Group		M±SD	t	p
Before	Treatment group	4.90±.598	.648	.52
	Control group	4.69±.814		
After	Treatment group	3.87±.494	-.091	.01*
	Control group	4.67±.650		

*p<.01

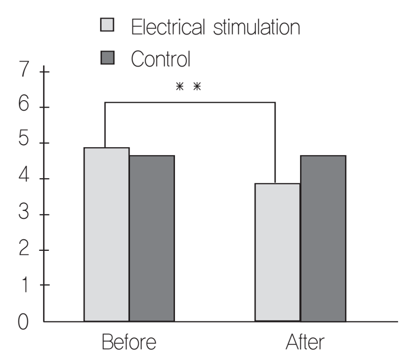

Fig. 3. Pronunciation /teo/ comparison between the treatment and control group before and after the treatment

DISCUSSION

Respiratory exercise is to help a patient to breathe stably and comfortably with normal breathing cycle and to prevent and reduce dyspnea. These respiratory exercises are used for patients with chronic obstructive pulmonary disease, patients who had chest relaxation abdominal surgery, patients with high risk of acute lung complications, and patients who have to spend long time on bed(6, 7, 8, 9).

Functional electrical stimulation can be used as one of these respiratory exercises. This stimulation was used by Liberson et al. in 1961 on hemiparalysis patients by stimulating peroneal nerve to treat foot drop(10). In 1996, Granat et al. reported that stimulating peroneal nerve had a direct effect on ankle dorsiflexion and eversion(11). In 1987, Wade et al. used functional electrical stimulation on muscle and nerve to cause functional movement(12). It reported that the stimulation reduced stiffness and improved muscle control ability while they were stimulated. Electrical treatments for stiffness reduction are antagonist muscle stimulation, agonistic muscle stimulation, and sensory training(13, 14, 15).

Physiologic mechanism of functional electrical stimulation can be classified into efferent functional electrical stimulation and afferent functional electrical stimulation. Efferent functional electrical stimulation stimulates motor nerve fiber and causes electrical excitation to generate neurotransmitter and contract muscle. Afferent functional electrical stimulation stimulates afferent nerve fiber to expand indirect effect of spinal reflex mechanism(16). In addition, it is reported that upper motor neurons lesion results in muscle contraction and change in muscle fiber composition ratio change(17).

That is, the ratio of Type Ⅰ muscle fiber with bigger resistance against fatigue than before the damage decreases relatively to Type Ⅱ muscle fiber which is why it is easier to feel fatigue. At this moment, if continuous functional electrical stimulation treatment is done, Type Ⅱ muscle changes to Type Ⅰ muscle resulting in less fatigue in muscle against electrical stimulation. Hudlicka et al. indicated the frequency that decreases this fatigue as 40-50Hz(18). Therefore, this study used 45Hz to induce constant contraction of respiratory muscle. Consequently, activated respiratory muscle might have affected forced vital capacity and phonation capability. Moreover, Cho reported that functional electrical stimulation on rectus abdominis muscle improved vital capacity and muscle activation in respiratory capability of cerebral palsy which is the same as the result of this study(19). In case of spinal cord injury patients who cannot have spontaneous respiratory, Kandare et al. conducted functional electrical stimulation on abdomen muscle and showed improved tidal volume and total lung ventilation(20). It also had similar result to this study. Functional electrical stimulation on abdomen muscle contraction the muscle and pushes the abdominal walls inward and increase intra-abdominal pressure.

It is considered that this moves diaphragm towards the thoracic cavity resulting in increased pleural pressure which in turn improving forced vital capacity. Breathing of children with spastic cerebral palsy has limited active and coordinated antigravity movement. Therefore, it directly affects respiratory functions, phonation, and sound production.

Moreover, abnormal muscle activity restricts anatomical development that is necessary for well-coordinated thoraco-abdominal respiration. When breathing, its rhythm, depth, and capacity are irregular. This weak respiration control brings dysphonia, hypophonia, problem in sounds, and disability in rhythm and pronunciation. When speaking, one should use intake air by a little bit as it is stored in the lung. Therefore, exhalation should be slow enough to speak while exhaling. And for continuous phonation, enough inhalation is necessary. So, it is important to have longer exhalation period than inhalation for utterance.

This study considers that improved respiration and lung capacity enhanced respiratory control for phonation and affected alternate motion rate for /peo/ and /teo/. This result is the same as the result of Ahn et al. that respiratory and phonation organ's training for treating and educating speech disorder of cerebral palsy improved the functions(21).

CONCLUSION

This study looked into the effect of functional electrical stimulation on forced vital capacity and alternating motion rate for the sounds /peo/ and /teo/ in children with spastic cerebral palsy. The study subjects were divided into two groups of the functional electrical stimulation treatment group and the control group. After four weeks of intervention, this study verified the significance of the effect between the two groups.

In case of maximal expiratory flow rate, both the functional electrical stimulation group and control group did not show any significant change before the intervention($p>.05$), but there was significant difference after the intervention($p<.05$). In case of alternating motion rate for the sounds /peo/ and /teo/, both the functional electrical stimulation group and control group did not show any significant change before the intervention($p>.05$), but there was significant difference after the intervention($p<.05$).

This result indicates that functional electrical stimulation on rectus abdominis muscle improved the children's weakened respiratory capacity and phonation.

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