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Effects of Combined Postural Correction Exercises on Selected Muscle Activity and Stiffness in Children With Cerebral Spastic Diplegia: Case Study

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융합적 자세교정치료가 뇌성경직양측마비 아동의 선택된 근육 활성도와 강직도에 미치는 영향: 사례연구

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Abstract The aim of this study was to investigate the short-term effects of combined postural correction exercises (CPCE) on muscle stiffness and muscle activity in children with cerebral spastic diplegia(CSD). The subjects were 3 children (2 male and 1 female) with CSD from 4 to 7 years old. The measurement sites were upper trapezius muscle(UT), rectus abdominis muscle(RA), and gluteus maximus muscle(Gmax), muscle stiffness and muscle activity were measured using Myoton and surface EMG, and the symmetry of both sides was also examined. As a result, children with severe compensatory action showed decreased muscle stiffness and muscle activity in UT and RA and increase in Gmax after CPCE intervention. Especially, the left and right symmetry of the muscles was decreased. In this study, despite some limitations, CPCE have shown a positive effect in posture correction of children with CSD.

Key Words : Case study, Cerebral spastic diplegia, Muscle activity, Stiffness. Short-term effect

요 약 본 연구에서는 뇌성경직양측마비 아동을 대상으로 융합적인 자세교정치료가 근강직도(muscle stiffness) 및 근활성도(muscle activity)에 미치는 단기적인 영향을 알아보고자 하였다. 연구 대상자는 4세부터 7세의 뇌성경직양측마비 아동 3명(남자2, 여자1)을 대상으로 하였다. 측정부위는 위등세모근, 배곧은근, 큰볼기근이며, 근강직도 측정기(Myoton)와 표면근전도(EMG)를 이용하여 근강직도와 근활성도를 측정하였으며, 양측 대칭성에 대해서도 알아보았다. 연구결과, 보상작용이 심했던 아동들이 융합적 자세교정 치료 중재 후 전반적으로 위등세모근과 배곧은근에서 근강직도와 근활성도가 감소하였고, 큰볼기근에서는 증가하는 경향을 보였다. 특히 해당 근육에서 왼쪽과 오른쪽의 대칭성이 줄어드는 특성을 보였다. 본 연구에서는 몇 가지 제한점에도 불구하고 융합적인 자세교정치료가 뇌성경직양측마비 아동의 자세교정 측면에서 긍정적인 효과가 있음을 보여 주었다.

주제어 : 사례연구, 뇌성경직양측마비, 근활성도, 근강직도, 단기효과

1. Introduction

Cerebral palsy is a clinical syndrome with impaired movement and posture due to non-progressive lesions or damage of the immature brain, and most cerebral palsy children have abnormal muscle tone such as

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stiffness, muscle weakness, ataxia, and coordination disorders[1]. In addition, there are abnormal and ineffective walking characteristics such as tiptoe walking, crouch walking, hyperextension of the knee joint, flexion and excessive adduction and internal rotation of the hip joint, and lumbar lordosis. In particular, tiptoe walking due to the rigidity of the plantar flexor is the most common abnormal walking characteristic of children with cerebral spastic diplegia[2]. The types of cerebral palsy are largely classified as spastic type, athetoid type, ataxic type, and hypotonic type[3]. Especially, the spastic type due to premature birth is increasing[4], and of these, diplegia is increasing[5]. Characteristics of children with cerebral spastic diplegia include the protrusion of shoulder bone with rounded shoulder, weakening of trunk, imbalance of lower limb and loss of balance due to this. Strengthening weakened trunk muscle strength increases stability in functional movements. This makes the behavior more accurate when the child performs the action[6]. If the muscular weakness of the trunk weakens the stability, it may cause a compensatory action on the arms and legs, and due to spinal deformity and contracture and abnormal alignment of the head and neck it may cause secondary malfunction. It can also cause balance problems in sitting and standing postures[7]. Therefore, it is possible to sit and stand, but there is a significant difference in symmetrical and harmonic muscle contraction in the joints and muscles of the balance and lower extremity, and the lack of weight shifting due to the muscle weakness of the lower extremity muscles makes it difficult for the children to walk[8]. Therefore, the goal of treatment is to reduce the asymmetry and compensatory action of children with cerebral palsy through coordination of muscle tone and harmonic contraction of the lower limb muscles including trunk. This requires posture control to maintain a stable posture against gravity in the pelvis, hip and lower extremities, and maintain normal body alignment state[9].

In addition to neurodevelopmental therapies, interventions involving children with cerebral palsy include a variety of exercises such as hydrotherapy, electrical therapy, sling, treadmill, and leg strength training. Among them, neurodevelopmental therapy is a strategy to inhibit abnormal reflexes and promote normal motor function, and is the basis of cerebral palsy therapy. It has also been considered as a classical method to induce reflex suppression and motor function through exercise and sensory stimulation and postural correction of children with cerebral palsy[8]. Although there are many treatments like this, the basic principle of treatment is to reduce compensatory action, deformation, and contracture due to abnormal development, and promote normal reflexes, tension and postural movements. Although many clinical physiotherapists and rehabilitation specialists have made efforts to treat children with cerebral palsy, there is still a lack of clinical evidence and research on these treatments[10].

In a previous study, 16 children with cerebral palsy were compared for the spinal alignment in the sitting position through intervention using elastic bands in the trunk, and as a result of the intervention, improvement of the trunk muscle strength reduced the fatigue of the sitting posture and gave stability to the spine to help prevent injury[11]. In addition, another study reported that when ball exercise and electric stimulus were applied to the trunk, they affected gross motor function and respiration, and the muscular strengthening exercises of the trunk affected the lower extremity muscles such as the knee joint bending muscle and the hip joint muscle. There were studies using diverse variables such as muscle tone and muscle activity, and many related studies have been carried out, including the relationship between type of walker and the muscle activity of the knee joint, the effect of rehabilitation riding on muscle activity and muscle tone of the lower limb, and changes in muscle activity during various activities such as standing and walking in cerebral palsy patients.

Table 1. Characteristics of the subjects (N=3)

Case	Gender	Age (years)	Height (cm)	Weight (kg)	GMFM[a] (%)	Assistive devices
1	male	5	108.3	18.5	87	use of walking aid
2	female	4	101.4	15.2	55	use of walking aid
3	male	7	126.4	26.2	64.74	use of walking aid

[a]Gross Motor Function Measure.

However, most studies have been conducted on the effects of one intervention method, and few studies have verified the effects of convergence of various intervention methods. Therefore, in this study, in children with cerebral palsy with characteristic cerebral spastic diplegia with difficulty in controlling the trunk muscle, the effect of combined postural correction exercises based on neurodevelopmental therapy on rectus abdominis muscle, gluteus maximus muscle and upper trapezius muscle using muscle stiffness meter and surface electromyography device was investigated, and through this the aim of this study was to identify the short-term effects of combined postural correction exercises as well as present clinically significant treatment methods.

2. Study Method

2.1 Study subjects

The subjects of this study were children with cerebral spastic diplegia (2 male and 1 female). The selection criteria of the subjects were, 1) Children diagnosed with cerebral palsy, 2) Children who can understand and perform the instructions given by the researcher, and 3) Children without vision and hearing impairment. In addition, children who did not agree to the study or withdraw from the study were excluded. The children and their caregivers were given enough explanation and received consent for the study, and all experiments were voluntary. The characteristics of the subjects are as follows(Table 1).

2.2 Measurement tools and procedures

2.2.1 Muscle stiffness measurement

To evaluate the muscle stiffness of upper trapezius muscle, rectus abdominis muscle, and gluteus maximus muscle before and after combined postural correction exercises for children with cerebral palsy, a muscle stiffness meter (Myoton AS, ESTONIA) [Fig. 1] was used. For the measurement posture, the upper trapezius muscle and the rectus abdominis muscle were measured in the supine position and the gluteus maximus muscle was measured in the prone position. In the measurement, the probe was measured perpendicularly to the surface of the skin and the measurement was repeated three times before and after the treatment.

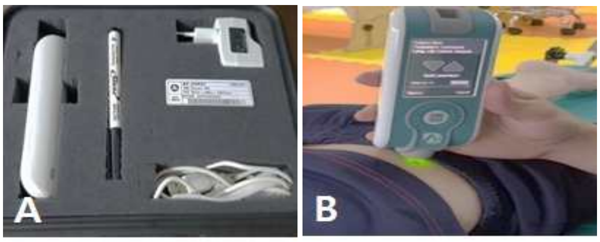

Fig. 1. Measurement of muscle stiffness(A: Myoton, B: Measurement of rectus abdominis)

2.2.2 Electromyography measurement

To measure the muscle activity of the upper trapezius muscle, the rectus abdominis muscle, and the gluteus maximus muscle in standng and walking before and after the combined postural correction exercises of children with cerebral palsy, surface electromyography(EMG)(Trigno, Delsys Inc, USA) equipment was used. EMGworks 3.7 (Delsys Inc, USA) software was used to analyze EMG signals wirelessly transmitted from the Trigno sensor to the Trigno base station. In order to minimize skin resistance, the

Table 2. Location of surface electrode

Muscle	Electrode location
upper trapezius	C7 spinous process ~ acromion process middle part
rectus abdominis	umblicus laterally 3cm
gluteus maximus	sacrum ~ greater trochanter middle part
vastus medialis	patella superior, medially 4cm, ASIS ~ patella 55° direction

electrode attachment area was cleaned with alcohol swap and then attached. The recording electrodes were arranged so as to be parallel to the running direction of the muscle fibers, and then collected through 6 channels. Muscle activity measurements were taken for 15 seconds in a relaxed posture facing forward. Data were collected for 9 seconds excluding the first and last 3 seconds, raw data were obtained, filtered to reduce confusion, and mean values of maximal voluntary isometric contraction were normalized and was used for analysis in this study[8].

2.2.3 Attachment sites

After confirming the position of the muscle, they were marked with a marker, and the surface electrodes were attached. The muscle attachment sites are as follows[12][13](Table 2).

2.3 Intervention method

Subjects participated in a treatment program (3 times a week) to correct posture. The intervention was conducted directly by a skilled specialist in a child rehabilitation hospital in Gyeonggi-do, and the intervention method consisted of a combination of posture correction intervention based on neurodevelopmental approach and balance training using ankle-foot orthosis in standing posture[14]. The contents of the combined postural correction exercises are as follows(Table 3).

3. Results

This study was performed to evaluate the muscle stiffness and muscle activity of children with cerebral palsy before and after combined postural correction exercises based on neurodevelopmental therapy, and the results are as follows.

3.1 Comparison of muscle stiffness before and after intervention through combined postural correction exercises

The mean and difference of muscle stiffness before and after intervention with combined postural

Table 3. Components of an exercise program

	contents	mode
1	Suppression of abnormal compensatory motion of the lower limbs and promotion of normal weight loading on both sides	• starting position: sitting → quadruped • repetition: 8
2	Applying movement through position change in various postures from lying to standing position	• starting position: lying → standing • repetition: 8
3	Maintaining postural changes in various BOSs with emphasis on reducing neck and shoulder tension	• starting position: supine → sitting • repetition: 10
4	Separate movement of the pelvis, trunk, and shoulders	• starting position: supine → sidelying • repetition: 10
5	The midline control with emphasis on maintaining the stability of the body and reducing the compensation of the arms.	• starting position: supine • repetition: 8
6	Standing balance training with foot orthosis	• starting position: standing • repetition: 8

Table 4. Comparison of muscle stiffness of the UT, RA, and G.max. (unit: N/m)

case		UT		change	RA		change	G.max		change
		pre	post		pre	post		pre	post	
1	R	159.67[a]	146.33	−13.34	227.33	211.00	−16.33	116.00	124.67	8.67
	L	346.34	214.67	−131.66	308.67	184.33	−124.34	143.33	148.33	5.00
2	R	243.67	236.33	−7.34	243.00	236.00	−7.00	113.33	124.67	11.34
	L	245.67	215.33	−30.34	239.67	223.67	−16.00	113.67	132.00	18.33
3	R	201.67	183.00	−18.67	114.00	114.00	0	120.00	178.00	58.00
	L	219.67	188.67	−31.0	134.00	125.67	−8.33	128.00	150.33	22.33

[a]mean, UT: upper trapezius, RA: rectus abdominis, G.max: gluteus maximus.

correction exercises were examined. The result values of the study are as follows(Table 4). The right muscle stiffness difference in case 1 was −13.34, −16.33, and 8.67 in the order of upper trapezius muscle, rectus abdominis muscle and gluteus maximus muscle, respectively, and the difference in the left muscle stiffness was −131.66, −124.34, and 5.00. The difference of right muscle stiffness in case 2 was −7.34, 7.00, and 11.34, and the difference of left muscle stiffness was −30.34, −16.00, and 18.33. The difference of right muscle stiffness in case 3 was −18.67, 0.00, and 58.00, and the difference of left muscle stiffness was 31.00, 8.33, and 22.33. In all 3 children, after intervention, muscle stiffness of upper trapezius muscle and rectus abdominis muscle decreased in left and right, but muscle stiffness increased in gluteus maximus muscle.

3.2 Comparison of muscle activity during walking through combined postural correction exercises

The mean and difference of muscle activity through walking with combined postural correction exercises were examined. The results of the study are as follows((Table 5). In the order of upper trapezius muscle, rectus abdominis muscle, and gluteus maximus muscle, in case 1, the right muscle activity difference was −22.15, −0.40, and 2.98, respectively, and the left muscle activity difference was −12.09, −0.52, and 5.62, respectively. In case 2, during walking, the right muscle activity difference was −15.60, −11.88, and 5.15, and the left muscle activity difference was −46.63, −11.99, and 3.05. In case 3, durign walking, the right muscle activity difference was 0.12, 0.24, and 0.87, and the left muscle activity difference was 0.94, −0.20, and 1.15. In case 1 and case 2, the muscle activity of the upper trapezius muscle and the rectus abdominis muscle during walking decreased in both left and right sides after the intervention, but there was no significant change in muscle activity in the gluteus maximus muscle. On the other hand, case 3 showed no significant change in all three muscles.

4. Discussion

The movement pattern of children with cerebral

Table 5. Comparison of activities of the UT, RA, and G.max in walking (unit: %MVIC)

case		UT		change	RA		change	G.max		change
		pre	post		pre	post		pre	post	
1	R	53.09	30.94	−22.15	19.96	19.56	−0.40	10.18	13.16	2.98
	L	41.64	29.55	−12.09	30.85	30.33	−0.52	13.38	19.00	5.62
2	R	28.74	13.14	−15.60	33.12	21.24	−11.88	9.55	14.70	5.15
	L	59.88	13.25	−46.63	43.65	31.66	−11.99	16.28	19.33	3.05
3	R	9.67	9.79	0.12	19.69	19.93	0.24	5.29	6.16	0.87
	L	7.93	8.87	0.94	30.65	30.45	−0.20	8.66	9.81	1.15

[a]mean, UT: upper trapezius, RA: rectus abdominis, G.max: gluteus maximus.

spastic diplegia lacks postural stability and mobility due to low muscle tone at the trunk region which causes stiffness in the legs. This results in lower mobility of the lower limbs and abnormal walking characteristics such as decreased balance ability. In addition, with the low muscle tone of the trunk, most children with cerebral spastic diplegia have insufficient head stability and due to neck muscles not functioning adequately, it makes it difficult to control the posture[15]. Therefore, it is important to provide training to children with cerebral palsy to stimulate neck righting reaction and trunk righting reaction, and to improve the rate of response of trunk muscles according to the shifting of weight. This training eventually improves the righting reaction of the neck and trunk, so that the child can maintain a more stable sitting posture and more easily perform standing of the upper body against gravity[16][17]. Training for posture control must be included as a component of the intervention program, and a comprehensive therapeutic approach including posture control in the treatment of children with cerebral palsy is a very important aspect. This study therefore aimed to investigate the short-term effects of combined postural correction exercises on muscle stiffness and muscle activity. For this purpose, in children with cerebral palsy, the muscle stiffness meter and surface electromyography were used to compare values before and after intervention in upper trapezius muscle, rectus abdominis muscle, and gluteus maximus muscle.

In the study results, in case A, after combined postural correction exercises, the left and right upper trapezius muscle(muscle stiffness) decreased by －12.09 N/m and －22.15 N/m, respectively, and rectus abdominis muscle(muscle stiffness) decreased by －124.34 N/m and －16.33 N/m, respectively. In addition, while muscle activity of upper trapezius muscle and rectus abdominis muscle was decreased, muscle activity of gluteus maximus muscle was increased. In muscle stiffness, the difference of boths sides of upper trapezius muscle was reduced from 186.66 N/m to 68.34 N/m, and the difference was also decreased in both sides of rectus abdominis muscle and gluteus maximus muscle. Also in case B, muscle stiffness of the left and right upper trapezius muscle and rectus abdominis muscle decreased. Moreover, muscle activity of upper trapezius muscle and rectus abdominis muscle decreased, but muscle activity of gluteus maximus muscle increased as in case B. The difference in muscle stiffness between left and right upper trapezius muscle and rectus abdominis muscle was decreased, but there was no significant difference in muscle activity. In case C, muscle stiffness of the left and right upper trapezius muscle and rectus abdominis muscle decreased. However, muscle activity slightly increased in all muscles. And muscle stiffness and muscle activity in gluteus maximus muscles were increased in all three children.

Previous studies have reported that the costal respiration pattern of the pectoralis major muscle decreased after correction of the sitting posture through trunk adjustment[18]. In addition, by applying lower extremity muscle strengthening exercises in children with spastic type cerebral palsy, there was increase in elements of balance and gait[19]. Also, there was improvements in walking speed and increase in stability. It was stated that in 5 children with spastic type cerebral palsy between ages 10-14, trunk stabilization exercise with sling exercise positively affected static foot pressure, bilateral symmetry on dynamic foot pressure, and balance. In addition, in effects of trunk stabilization exercise using Swiss ball for 8 weeks on gross motor function in 9 children with spastic type cerebral palsy, there was significant influence in standing, walking, running, and jumping, which implies that trunk exercise has positive effects on standing and walking[20][21][22]. Various studies have shown that the trunk strengthening exercise applied to children with cerebral palsy improves the stability by reducing the compensatory action significantly, and also positively affects gait and balance as well as functional activities[23][24]. Also in this study, it was confirmed that in the upper trapezius muscle with increased muscle activity due to lack of trunk stability, the muscle activity was reduced after combined postural correction exercises intervention. These results can be considered similar to that of the trends of preceding studies.

However, there were no significant differences in the study of muscle tone through trunk strengthening exercises in 16 children with spastic type cerebral palsy using the modified motor assessment scale (MMAS)[25]. This is considered to be because subjective measurement tools were used, unlike this study using objective measurement tools to obtain quantified data values.

In addition, walking may be the final goal of the motor function of children with cerebral palsy, and it is an important activity to represent the gross motor function as a whole. In this regard, in this study, it was found that the postural correction intervention method was effective in improving gait improvement and functional aspects, as the muscle activity of both sides decreased and symmetry increased during walking in specific children after the intervention. However, the limitations of this study were the lack of number of subjects and the short intervention period of the combined postural correction exercises that only demonstrated short-term effects. In later studies, if more than one month of intervention is performed on more samples, it is considered that it will be of great help in establishing a clinically effective customized intervention program.

5. Conclusion

The study examined short-term effects of combined postural correction exercises on muscle stiffness and muscle activity and bilateral symmetry in children with cerebral spastic diplegia. As a result, in children with severe compensatory action, muscle stiffness and muscle activity decreased overall in the upper trapezius muscle and rectus abdominis muscle after the combined postural correction exercises intervention, and there was a trend of increase in the gluteus maximus muscle. Especially, in the specific muscle, the left and right symmetry of the muscle was decreased. Despite some limitations, this study showed that combined postural correction exercises had a positive effect on the posture correction of children with cerebral spastic diplegia. In future studies, it is considered that the number of subjects should be increased and various treatment programs should be applied over a long period of time in accordance with the characteristics of related children for the development of effective therapeutic intervention methods.

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