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Original Article

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Effect of Strength Training Combined with Blood Flow Restriction Exercise on Leg Muscle Thickness in Children with Cerebral Palsy

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| Abstract |

Purpose: The purpose of this study was to investigate the effect of strength training combined with blood flow restriction on leg muscle thickness in children with cerebral palsy.

Methods: Nineteen children with cerebral palsy, aged between five and 10 years of age, living in area N, were recruited. Ten participants were classified into a blood flow restriction group and nine into a strength exercise group. The experimental group performed strength training using a blood flow restriction cuff on the leg, and the control group performed strength training without blood flow restriction. A paired t-test was performed to confirm intragroup changes before and after five weeks of the experiment, and an independent t-test was performed to confirm intergroup changes, and the significance level was $\alpha=0.05$.

Results: The rectus femoris, gastrocnemius and gluteus medius muscles showed significant differences in the groups after five weeks ($p<0.05$). There was a significant difference between the groups in the rectus femoris and gastrocnemius after five weeks ($p<0.05$).

Conclusion: As a result of this study, it was found that strength training combined with blood flow restriction had a positive effect on the changes in leg muscle thickness in children with cerebral palsy. This suggests the possibility of using it in the future as basic data for strength training methods and blood flow restriction exercises for children with cerebral palsy.

Key Words: Edema, Pumping exercise, Elastic compression stockings

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Ⅰ. Introduction

Cerebral palsy, which makes it difficult to move independently due to various motor disorders such as spasticity, unstable gait, restriction of daily living activities, difficulty in movement, and balance problems, is defined as a neurodevelopmental disorder including impairment of physical or behavioral functions (Peterson & Hurvitz, 2021; Stavsky et al., 2017).

The management goal of cerebral palsy (CP) is improving functionality, locomotion and independence (Barak et al., 2014). Increase in functional and independent movement in children with cerebral palsy has a positive effect on achievement of daily living activities and motivation for social participation (Reid et al., 2011).

Compared to normal children, children with cerebral palsy use fewer motor units during voluntary muscle contraction (Pool et al., 2014). They use 56% and 73% fewer motor units in the knee extensors and plantar flexors compared to normal children (Stackhouse et al., 2005). In addition, 90% of them had problems with walking instability and 54% had difficulty walking alone (Kadhim & Miller, 2014).

Functional and independent movements require strengthening of trunk stability and strengthening of leg muscles (Sharma et al., 2012). However, despite the efforts of physical therapists, it is difficult to find an effective proven method for increasing activities of daily living and improving movement in cerebral palsy (Peterson & Hurvitz, 2021).

Studies related to the independent improvement of cerebral palsy include improvement of gait pattern using theratogs, intervention through orthosis, surgical method, stabilization exercise, and vibration method, but it requires a lot of economic cost and time (Abd-Elfattah & Aly, 2021; El-Shamy & Abd El Kafy, 2021; Oudenhoven et al., 2021; Salazar-Torres et al., 2021) Salazar-Torres et al., 2021).

Recently, blood flow restriction exercise, which restricts blood flow in the arms and legs, can be applied to various exercises related to changes in the body, muscle mass, strength, and mobility (Patterson et al., 2019).

In blood flow restriction exercise, the application of low-intensity resistance exercise (1 RM 20%) similarly to high-intensity resistance exercise has the same effect on muscle hypertrophy, strength and endurance improvement (Fujita et al., 2007; Loenneke et al., 2012; Sata, 2005). Previous studies have reported that blood flow restriction exercise increased muscle size in adults (Laurentino et al., 2012) and the torque of quadriceps femoris and hamstring muscle in knee surgery patients (Noyes et al., 2021).

Blood flow restriction exercise has been reported to improve muscle strength, muscle weight, and quality of life in patients with rheumatoid arthritis (Rodrigues et al., 2020), and also had a positive effect in patients with degenerative arthritis (Ferlito et al., 2020).

However, most studies are limited to patients with musculoskeletal disorders, normal adults, and the elderly, and studies on changes in leg muscle thickness related to neurological diseases or functional movements are currently lacking.

Therefore, this study investigates the effect of strength exercise including blood flow restriction exercise on the leg muscle thickness of cerebral palsy, and suggests an appropriate intervention method and the utility of basic data in clinical practice.

Ⅱ. Method

1. Subject

This study was conducted on children with cerebral palsy who received physical therapy at Institution D located in Daegu from February 9 to March 16, 2020. And the subjects were children aged 5 to 10 years with spastic cerebral palsy, which correspond to the gross motor function classification system Level I-II. The subjects were 9 boys, 11 girls, and a total of 20 people, and using a randomization method, 10 people in the blood flow restriction with muscle strength group (BWMG), and 10 people in the muscle strength group (MG) consisted of 10 people.

The sample size was selected using G*power3.1 based on the previous study, and the effect size (d=1.6901018), significance level (α =0.05), and power (1-β =0.90) were set. A total of 18 people were selected for this study, and a total of 20 people were recruited considering the dropout rate.

After 5 weeks, one control group dropped out, and 19 people finished the experiment. The subjects of this study were children with cerebral palsy, who could maintain an independent standing posture without assistive devices, can walk, communicate well, understand exercise methods, and have cognitive abilities to the extent that they can participate in exercise. The purpose and process of this study were conducted with sufficient explanation and informed consent in accordance with the Declaration of Helsinki for children with cerebral palsy and their guardians. Subject exclusion criteria for this study were those who had surgery, and seizures or epilepsy in the past 2 years.

2. Experimental procedure and exercise method

All groups were treated with neurodevelopmental therapy for 15 minutes before exercise. A blood flow restriction cuff was used between the hip and knee joints to apply a pressure of 100 mmHg from weeks 1 to 2 and a pressure of 110 mmHg from weeks 3 to 5.

The type of exercise of the experimental group and the control group was applied by changing the method of Ryu and Son (2011). The exercise types were plantar flexion and knee joint extension. The plantar flexion exercise was performed by bending the knee joint at 90° in the prone position and applying resistance to the metatarsal bone.

For knee extension exercise, after sitting on a chair, the knee joint was bent by 90°, and resistance was applied to the distal part 5 cm anterior to the outer malleolus. However, the control group did the same strength training as the experimental group without restricting blood flow, and all exercises were performed for 5 weeks. All exercises were performed 3 times a week for 5 weeks with a total of 4 sets of 3 minutes training, 2 minutes rest, and 20 minutes a day. During the intervention, the physical therapist encouraged the child and closely observed that various side effects did not occur. If any abnormal symptoms such as redness or pain occurred on the skin, the exercise was stopped immediately.

3. Measurement

An ultrasound imaging device (MyLabOne, Esaote, Italy) was used to measure the thickness of the leg muscles. Its frequency was 6～9MHz, and the transducer used a 7.5MHz linear transducer to measure the thickness of rectus femoris, gastrocnemius and gluteus medius muscles. To measure the thickness of the rectus femoris muscle, a cushion was placed behind the knee joint after lying down, and a line was drawn from the anterior superior iliac spine to the patella at 30° of knee joint flexion and taken as one-third of this line. To measure the thickness of gastrocnemius, a cushion was placed on the ankle to prevent the ankle dorsiflexion in prone position, and then a line was drawn between the knee joint and the middle of the ankle joint and measured at one-third point. The muscle thickness of gluteus medius was measured at the one-third point of the trunk between the great trochanter and the iliac crest. All measurements were performed three times and the average value was used.

4. Data analysis

All data were processed using SPSS 19.0 (SPSS Inc., USA). In addition, Shapiro-wilk test was performed to confirm whether the subjects had a normal distribution. The paired t-test was used for the changes in leg muscle thickness before and after 5 weeks in both groups, and the independent t-test was used for the changes between groups after 5 weeks. The α value was set to 0.05.

Ⅲ. Results

1. General characteristics of subjects

The experimental group of this study consisted of 5 boys and 5 girls, a total of 10 people, with an average age of 6.60±1.17 years, height of 100.00±10.82cm, and weight of 18.20±7.61kg. The control group consisted of 5 males and 4 females, with an average age of 6.88±1.16 years, height of 98.44±7.10 cm, and weight of 17.88±4.67 kg (Table 1).

2. Changes in the thickness of the rectus femoris according to the intervention method

There was a significant difference in BWMG ($p<0.05$) in the intragroup change in the thickness of the rectus femoris muscle according to the intervention method, and there was a significant difference in the group change after 5 weeks between the experimental and control groups ($p<0.05$).

3. Changes in the thickness of the gastrocnemius according to the intervention method

The intragroup change in the gasrocnemius thickness according to the intervention method had a significant difference in BWMG ($p<0.05$), and there was a significant difference between groups after 5 weeks between the experimental and control groups ($p<0.05$).

4. Changes in the thickness of the gluteus medius according to the intervention method

There was a significant difference in BWMG in the intra-group change in the gluteus medius thickness according to the intervention method ($p<0.05$), and there was no significant difference between groups after 5 weeks between the experimental and control groups ($p>0.05$).

Table 1. General characteristics of subjects (n=19)

	BWMG (n=10)	MG (n=9)	p
GMFCS level (I-II)	8	7	
	2	1	
Gender (M/F)	5/5	5/4	
Age (years)	6.60±1.17	6.88±1.16	0.35
Height (cm)	100.00±10.82	98.44±7.10	0.52
Weight (kg)	18.20±7.61	17.88±4.67	0.35

BWMG: blood flow restriction with muscle strength group, MG: muscle strength group, GMFCS: gross motor function classification system
Mean±SD

Table 2. A comparison of between pro-post (mm)

		BWMG	MG	t	P[3]
RFT	Pre	0.72±0.09	0.70±0.08	3.11	0.01*
	Post	0.88±0.10	0.72±0.12		
	Difference[1]	0.14±0.08	0.02±0.05		
	t	5.77	0.78		
	p[2]	0.00*	0.46		
GCT	pre	0.57±0.14	0.52±0.13	2.73	0.01*
	post	0.72±0.14	0.54±0.16		
	difference[1]	0.16±0.08	0.02±0.05		
	t	6.26	1.51		
	p[2]	0.00*	0.17		
GMT	pre	0.45±0.18	0.50±0.11	1.82	0.09
	post	0.62±1.16	0.51±0.80		
	difference[1]	0.16±0.07	0.01±0.06		
	t	7.23	0.54		
	p[2]	0.00*	0.60		

RFT: rectus femoris thickness, GCT: gastrocnemius thickness, GMT: gluteus medius thickness, BWMG: blood flow restriction with Muscle strength group, MG: muscle strength group [1]Difference: post-pre, [2]Paired t-test, [3]Independent t-test, Mean±SD, *$p<0.05$

Ⅳ. Discussion

The purpose of this study was to investigate the effect of plantar flexion exercise and knee extension exercise combined with blood flow restriction on the thickness of the rectus femoris, gastrocnemius, and gluteus medius muscles in children with cerebral palsy.

The main function of skeletal muscle is to generate force to produce movement (Howard & Herzog, 2021). There are structural differences in spastic cerebral palsy compared to the muscles of normal children as there are structural changes in the muscle size reduction, contractile tissue reduction, and excessively elongated sarcomere (Howard & Herzog, 2021).

Barbalho et al. (2019) investigated the effect of blood flow restriction on muscle wasting in 34 elderly patients in ICU. And it was reported that blood flow restriction was superior to the existing treatment.

Noble et al. (2014) reported that the leg muscles of 19 children with spastic cerebral palsy had an average 27.9% decrease in muscle mass compared to normal children. Rose and McGill (1998) reported that children with spastic cerebral palsy produced only 50% of calf muscle force when walking compared to normal children. In addition, Lieber and Fridén (2019) reported that muscle contracture in children with cerebral palsy results in permanent shortening of the muscle-tendon unit, loss of elasticity, and joint deformation (Howard & Herzog, 2021).

The optimal length of sarcomere is 2.64㎛ to 2.81㎛, if longer or shorter than this, the muscle strength decreases (Herzog et al., 1990). Lieber and Fridén (2019) found that the average length of sarcomere in children with cerebral palsy was 3.5-4.0μ m, while that of adductor longus in normal children was 2.6μ m, whereas in cerebral palsy it was 3.6μ m (Leonard et al., 2019) reported the need to increase muscle strength and muscle thickness.

The blood flow restriction exercise in this study has the effect of increasing muscle thickness and improving muscle strength. This is thought to be an increase in the anabolic action of the muscle through the improvement of muscle strength.

Hill (2020) observed eccentric torque, afferent torque, isometric maximal torque, muscle activation, and muscle thickness in the opposite leg through afferent resistance exercise using blood flow restriction in 36 women. As a result of the study, there was muscle activation and muscle strength increase without change in muscle size. Therefore, it was suggested that low-load eccentric blood flow restriction exercise could be a special alternative for increasing and maintaining the muscle strength of the contralateral extremity and could be applied to the rehabilitation of paralyzed patients. Centner and Lauuber (2020) reported that blood flow restriction exercise promoted nerve changes and there was no significant difference in the thickness change of gluteus medius after blood flow restriction. However, this needs to be confirmed by increasing the study period. This is consistent with the gluteus medius through blood flow restriction in this paper.

Korkmaz et al. (2020) reported an increase in the strength of the knee flexor and extensor muscles through low-intensity blood flow resistance exercise for 23 young soccer players for 6 weeks. In this study, there was a significant difference in the within-group change in the thickness of the rectus femoris muscle in the blood restriction exercise group, and there was a significant difference in the change between groups after 5 weeks. It is thought that the low-intensity blood flow restriction exercise had an effect on muscle activation and muscle strength increase of the thigh muscles through neural adaptation of motor units. In other words, it is thought that neural adaptation through muscle strengthening is the induction of interneuron inhibition at the spinal cord level.

Cardozo et al. (2021) investigated the acute effects of physical exercise on vascular reactivity, muscle hypertrophy, endothelial cell function, and biomarkers of oxidative stress using various blood flow restriction in 68 young and elderly subjects. As a result, it could be helpful to explain the age-related effects of blood flow resistance exercise on maximal muscle strength improvement, growth hormone increase, and vascular health and the effects of stability. This is consistent with the improvement of gastrocnemius and rectus femoris strength in this paper.

Giles et al. (2017) reported that strengthening the quadriceps femoris muscle combined with low-intensity blood flow restriction in 35 knee pain patients was effective in reducing pain and increasing knee extension torque in activities of daily living. This is consistent with the improvement of gastrocnemius and rectus femoris strength in this paper.

There was a significant difference in the within-group change in the gastrocnemius thickness in the blood flow restriction exercise group in this study, but there was no significant difference in the group change after 5 weeks. This is thought to be that blood flow restriction exercise had an effect on maximal strength improvement of gastrocnemius and growth hormone increase.

Letieri et al. (2018) studied the effects of 16 weeks of resistance training using different occlusion pressures and post-exercise on muscle strength levels in 56 elderly women who enjoyed leisure activities. Douris (2018) et al studied the effect of gait exercise with blood flow restriction in 65 Parkinson’s disease patients. As a result, improvement in gait, reduction of symptoms of restless legs syndrome, and maintenance of recreational activity were reported. And it was said that gait with blood flow restriction exercise is an effective and safe intervention for recreational activities. As a result, it was reported that low-intensity blood flow restriction resistance exercise was as effective as high-intensity exercise in increasing muscle strength and nerve adaptation in elderly women. This is consistent with the improvement of gastrocnemius and rectus femoris strength in this paper.

Centner and Lauber (2020) reported that 10 blood flow restriction exercises promote neural alterations in fields of central activation and corticospinal excitation.

In this study, there was a significant difference in the intra-group change of gluteus medius thickness in the blood restriction exercise group, and there was no significant difference in the change in the group after 5 weeks. It is thought that the increase in the strength of the gluteus medius did not lead to a sufficient degree of improvement in the neuroadaptive capacity of the motor unit through blood flow restriction exercise. The limitation of this study is that a small number of cerebral palsy in a specific region were targeted, and thickness changes of several muscles were not confirmed, and only specific muscles were identified, so it is difficult to generalize them. However, the changes identified as a result of this study are considered positive. In the future, qualitative research targeting various types of cerebral palsy and research on muscle changes after blood flow restriction are also needed.

Ⅴ. Conclusion

The purpose of this study was to determine the thickness changes of the rectus femoris, gastrocnemius, and gluteus medius during leg strength exercise with blood flow restriction in children aged 5 to 10 years with cerebral palsy. There was a significant difference in the changes in the rectus femoris, the gastrocnemius and the gluteus medius within the group, and there was also a significant difference in the group change after 5 weeks. In the future, it can be expected that the physical function of cerebral palsy will be improved and maintained through appropriate exercise with blood flow restriction.

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