

The Effect of Functional Training Using a Sliding Rehabilitation Machine on the Mobility of the Ankle Joint and Balance in Children with CP

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| Abstract |

PURPOSE: The purpose of this study was to investigate the effect of functional training using a sliding rehabilitation machine (SRM) on the mobility of the ankle joint and balance in children with cerebral palsy (CP).

METHODS: The subjects consisted of 11 children who were diagnosed with spastic CP. They carried out the functional training using the SRM for 30 minutes, three times a week, for 8 weeks. Before and after all of the training sessions, the subjects were tested using the Pediatric Balance Scale (PBS) and Gross Motor Function Measurement (GMFM), range of motion (ROM) in the ankle joint, the pennation angle of the gastrocnemius muscle and the fascicle length of gastrocnemius muscle were measured to determine the mobility of the ankle joint and balance ability.

RESULTS: There were significant differences between the pre-test and post-test in the PBS and GMFM. The ROM of the ankle joint was significantly increased after the functional training using the SRM. Moreover, the fascicle

length was increased and the pennation angle was decreased after the functional training using the SRM, but the difference was not significant.

CONCLUSION: These results suggest that functional training using the SRM may have some effect on the mobility of ankle joint and balance in children with CP. According to the results, this study could present an approach to the rehabilitation or treatment of children with CP.

Key Words: Cerebral palsy, Sliding rehabilitation machine, Mobility of the ankle joint, Balance

I. Introduction

Cerebral palsy (CP) can be defined as permanent impairments in movement and postural development which cause limitations in activity, abnormal movement patterns and so on (Bax et al., 2005). Although the brain injury is not progressive, the musculoskeletal impairments accumulate as the child grows, resulting in secondary impairment such as spasticity, abnormal muscle tone, contracture, coordination, and selective movement control (Gage & Novacheck, 2001). In particular, spasticity with muscle weakness is the most common cause of the limited range of motion

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(ROM). Ankle articulation is the main joint exhibiting abnormal contracture and limited ROM; the limited ROM of the ankle joint impedes balance control and functional performance (Eek & Beckung, 2008; Mecagni et al., 2000; Menz et al., 2005; Menz et al., 2006).

The common feature of ankle impairment is a morphological change in the gastrocnemius muscle. It has been reported that the length, volume and pennation angle of the gastrocnemius muscle in children with CP are decreased comparing with those of normal children (Fry et al., 2004; Malaiya et al., 2007; Mohagheghi et al., 2008; Moreau et al., 2009). In addition, these changes in the gastrocnemius muscle are associated with the functional impairment in ankle joint and are closely correlated with the limited ROM and balance in children with CP (Neptun et al., 2001).

Muscles such as the tibialis anterior, soleus, and gastrocnemius muscle are related to the ankle ROM and balance. The representative exercise including these muscles is the sit-to-stand (STS) exercise. This exercise is a very effective way of improving the balance and functional activity of children with CP (Liao et al., 2007, Scholtes et al., 2010).

However, the sit-to-stand exercise has some limitations. First, it is limited to certain children: To perform the STS exercise, children basically need to be able to stand against gravity. Second, it is difficult for hemiplegic patients to perform selective exercise. To compensate for these problems, Lee et al. (2007) developed a sliding rehabilitation machine (SRM) which can provide weight support during closed-chain exercise for hemiplegic patients. It is reported that the SRM can provide the strengths of weight support and forced exercise simultaneously. In addition, training using the SRM is very effective in patients with stroke when it comes to improving muscle strength and balance ability (Byun et al., 2011).

Previous studies on the effects of the SRM have been limited to stroke patients (Byun et al., 2011). Therefore,

evidences on its effectiveness still need to be gathered in relation to children with CP, especially focusing on the ankle joint. Thus, the aim of this study was to investigate the effect of training using the SRM in children with CP. It is hoped that this work will present evidence on an effective method of rehabilitation for this patient population.

II. SUBJECTS AND METHODS

1. Subjects

Children with CP who were outpatients at D clinic in Daegu were randomly recruited for this study. The inclusion criteria were as follows: 1) Gross Motor Function Classification System (GMFCS) level I - III; 2) age from 6 to 18 years; and 3) the ability to follow verbal instruction. Children who had been treated with Botox or surgical operation within 6 months were excluded. Informed consent was obtained from children's patients after all information such as the purpose, method, advantages or inconvenience, risk, and test schedule of the study were presented to them. Ultimately, 11 children participated in this study (Table 1).

Table 1. General characteristics of subjects.

Subject	Age	Sex	GMFCS	Type
1	15	Male	3	Quadriplegia
2	11	Male	2	Rt. Hemiplegia
3	13	Female	2	Lt. Hemiplegia
4	11	Male	2	Lt. Hemiplegia
5	16	Male	2	Diplegia
6	18	Male	3	Diplegia
7	15	Male	3	Quadriplegia
8	14	Female	2	Lt. Hemiplegia
9	9	Male	3	Diplegia
10	18	Female	3	Quadriplegia
11	8	Male	2	Diplegia

2. Methods

A sliding rehabilitation machine was used in this study. This machine comprising patient-supporting carriage, footplate, Velcro strap for safety, and rail system that can help the patients to carry out the exercise by moving the carriage up and down using the wheels on the rail system. The wheels minimize frictional force, making the STS exercise easier. Patients with difficulty achieving full contact between the plate and the soles of the feet because of the severe plantar contracture can also carry out the exercise by controlling the inclination of the footplate to broaden the contact surface. In addition, the level of exercise can be changed according to the patients' ability by adjusting the inclination of the supporting carriage. During the exercise, a Velcro strap was used to fix the patients' trunk and ankles for their safety (Fig 1).



Fig 1. sliding rehabilitation machine

All children who participated in this study trained with the SRM for 30 minutes a day, twice a week, for 8 weeks with concurrent conventional Bobath therapy. Every training session was carried out under the supervision of experienced physical therapist to prevent any accidents and to help children carry out the correct exercise with the proper posture.

Some tests for balance ability, such as the Gross Motor Function Measurement (GMFM) and Pediatric Balance Scale (PBS) were performed at the beginning and the end

of this study.

To compare the morphological changes in gastrocnemius muscle measurements of the pennation angle and fascicle length were taken using a sonograph (Accuvix V10, Samsung Medicine, Korea) and the ROM of the ankle joint was also measured to investigate the improvement in mobility of this joint.

The participants were lying in a prone position with knee and hip joint angles at 0° (full extension). Ultrasonography was visualized in a continuous sagittal plane ultrasound image while the ultrasound probe is moved across the surface of an gastrocnemius muscle. The probe was aligned to the middle of the muscle belly. Fascicle length was calculated from the muscle thickness and pennation angle. The gastrocnemius muscle thickness was measured halfway along the lower leg. The gastrocnemius muscle pennation angle was determined from the angle of insertion of the fascicle into the deep aponeurosis. Thickness and pennation angle were measured every 5° from 0° to 30° of ankle dorsiflexion. The fascicle length was calculated from: $\text{fascicle length} = \text{muscle thickness} / \sin \theta$ (pennation angle) (Nakamura et al., 2011).

3. Data and statistical analysis

SPSS version 18.0 for windows was used for statistical analysis. The Shapiro-Wilk test was used for the test of normality. The paired t-test was used to compare before and after training with the SRM and Wilcoxon's signed rank test for values not to meet normality were used. Results were considered to be statistically significant if the P-value was less than 0.05.

III. Result

The GMFM and PBS scores were significantly improved after training using the SRM. Table 2 displays the differences between pre- and post-testing in terms of the

GMFM and PBS scores.

The ROM for dorsiflexion of the ankle joint was significantly improved; the mean values of pennation angle and fascicle length were also increased, but the difference was not statistically significant. Table 3 shows the differences between pre- and post-testing in ROM, pennation angle, and fascicle length.

Table 2. Comparison of GMFM and PBS score between pre-test and post-test

	Pre (Mean±SD)	Post (Mean±SD)	p
GMFM score	58.59±1.62	60.34±2.14	.01*
PBS score	37.22±1.39	39±1.24	.01**

Mean±SD: Mean±Standard deviation

GMFM: Gross Motor Function Measurement

PBS: Pediatric Balance Scale

*p<.05

**p<.01

Table 3. Comparison of ROM of ankle dorsiflexion, pennation angle, and fascicle length between pre- and post-test

		Pre (Mean±SD)	Post (Mean±SD)	P
ROM (degree)		12.83±6.49	16±5.36	.01**
	-20	30.68±0.99	29.85±0.87	.02
pennation angle (degree)	10	27.45±1.51	26.76±1.32	.16
	0	24.81±4.87	24.16±6.12	.25
	10	22.31±1.70	21.77±1.34	.32
fascicle length (cm)	-20	2.04±0.74	2.04±0.74	.83
	10	2.22±0.88	2.28±0.85	.21
	0	2.43±0.91	2.53±0.95	.19
	10	2.66±0.88	2.81±0.95	.03*

*p<.05

**p<.01

IV. Discussion

The present study was conducted to investigate the effect of STS training with the SRM on the ankle joint and balance

in children with CP. It has been reported that STS exercise has four characteristics, namely specialty, intensity, frequency, and quantity; thus, it has a more profound effect on gait and balance than other exercise (Rosen & Dickinson, 1992; Yeargin-Allsopp et al., 2008). However, STS exercise has some disadvantages, such as a limitation in terms of which children can carry it out, the impossibility of selective exercise, vulnerability to falls, and other secondary problems. In order to evaluate and revise these disadvantages, Byun et al. (2011) reported that training with the SRM led to a positive effect on gait and balance in chronic hemiplegia patients after stroke.

In this study, the pennation angle of the gastrocnemius was decreased and the fascicle length of the gastrocnemius was increased, although not statistically significantly, in children with CP after training using the SRM compared to before the training. Barber et al. (2011) reported that increased pennation angle and decreased fascicle length of gastrocnemius were fairly related to abnormal deformities of the ankle joint such as equinus, pes varus, and pes planus, which hinder the mobility of dorsiflexion (Huijing et al., 2013; You et al., 2009; Lee et al., 2011). In addition, a study of children with CP reported that passive stretching and active exercise improve mobility of the ankle joint, and it was confirmed that there were significantly decreased pennation angles and increased fascicle lengths after exercise. As a result, the study reported that mobility of the ankle joint was also effectively improved (Nakamura et al., 2011). Moreover, one previous study explained that decreased pennation angle of the gastrocnemius and increased fascicle length suggest improved extensibility of the gastrocnemius, resulting in increased dorsal mobility of the ankle joint (Neptune RR et al., 2001). Some other studies have also shown that the thickness of the muscle belly, muscle volume, and fascicle length tend to increase after active strength exercise (Wu et al., 2011; Toner et al., 1998; Riad et al., 2012; McNee et al., 2009). The present study showed decreased pennation angle and increased

fascicle length after training, but the differences were not statistically significant. However, the results are considered to have been affected by the limited number of subjects and the fact that the intervention period was too focused on one issue and too short to be comprehensive.

The present study showed that ROM of the ankle joint increased after training, and the difference was statically significant. A previous study reported that tibialis anterior is most activated when STS exercise is performed. It was found that this activation of the tibialis contributes to the dorsiflexion of the ankle joint and stability of foot and tibia; moreover, angular acceleration of trunk is improved because the activation facilitates flexion of the hip joint(Doorenbosch et al, 1994, Vander Linden et al, 1994). Moreover, STS exercise effectively helps to increase strength of the tibialis anterior, which improves the dorsal torque of the ankle joint. As a result, it was reported that strength training may effectively help patients who have deformity like equinus or plantar flexion contracture, thereby improving the mobility of the ankle joint.

The present study also showed that PBS scores, which evaluate the balance ability of children with CP, and GMFM scores were statistically significantly increased. Spink et al.(2011) reported that strength and ROM in the foot and ankle joint have considerably relevance to balance ability and functional performance capability. It was reported that passive stretching exercise in patients with contracture deformity of the foot and ankle joint, such as children with CP, can improve balance ability by increasing the extendibility of the gastrocnemius(Nakamura et al, 2011). In another study, it was stated that increased ROM of the ankle joint was exhibited and balance ability was improved not only after passive stretching exercise, but also training that included active functional exercise such as stair-climbing and STS exercise(Wuebbenhorst & Zschorlich, 2011). Furthermore, Byun et al.(2011) reported that the balance ability of patients with hemiplegia was increased significantly after training with the SRM.

Regarding this, Khemlani et al.(1999) additionally stated that the enhancement of the patient's ability to balance was a result of how the tibialis anterior, soleus muscle, and gastrocnemius and other muscles near the ankle joint were activated by the STS exercises. The exercises activated these muscles, stabilizing the knee joint(Khemlani et al., 1999; Winter, 1980). In addition, it was shown that the strength of the quadriceps femoris, as well as the ankle joint, was greatly improved after strengthening exercises like STS. Improving the strength of the quadriceps femoris makes possible not only effective mobility and stability of the pelvis, but also makes it easier for the subject to move his or her center of gravity into the base of support by activating the trunk muscle when sitting or standing. This mechanism may result in an improvement in the balancing abilities of children with CP, which is considered to be important in helping them to perform daily tasks.

The present study has some limitations. First, due to the small number of subjects, comparisons between groups could not be made. Second, focusing on one characteristic aspect of CP type restricted the results. Finally, the intervention period was too short to obtain concrete evidence. Due to these limitations in the experiment, it is difficult to accurately generalize the effect of the SRM to other cases. In conclusion, future studies must overcome these limitations in order to produce more objective evidence.

V. Conclusion

The findings of this study indicated that strength training using an SRM increased the ROM of the ankle and the balance function in children with CP. We also found that the pennation angle of the gastrocnemius was decreased and fascicle length of the gastrocnemius was increased in children with CP after training using sliding rehabilitation than before, but the differences were not statistically

significant. These study data suggest that SRM training may increase the ROM of the ankle and balance and can be applied in the treatment of children with CP. Further studies are needed that include greater numbers of participants and more specific methodological procedures to clarify the effects of SRM training on children with CP.

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