

Effects of trunk-hip strengthening on standing in children with spastic diplegia: a comparative pilot study

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Abstract. [Purpose] This study evaluated the effects of trunk-hip strengthening exercise on trunk-hip activation and pelvic tilt motion during standing in children with spastic diplegia and compared the improvement of pelvic tilt between the modified trunk-hip strengthening exercise and conventional exercise. [Subjects and Methods] Ten ambulant children with spastic diplegia were randomized to the modified trunk-hip strengthening exercise ($n = 5$) or conventional exercise ($n = 5$) group. The intervention consisted of a 6-week modified trunk-hip strengthening exercise 3 times per week. The children were tested for trunk-hip muscles activation and pelvic tilt motion during standing by surface electromyography and an inclinometer before and after the intervention. [Results] The anterior pelvic tilt angle and activation of the extensor spinae, rectus femoris, and semitendinosus during standing decreased significantly in the modified exercise group. The activation of extensor spinae differed significantly between groups. [Conclusion] Compared to the conventional exercise, the modified exercise was more effective for trunk-hip activation improvement and anterior pelvic tilt motion decrease during standing in children with spastic diplegia. We suggest clinicians use an individually tailored modified trunk-hip strengthening exercise for strengthening the weakest muscle groups in children with standing ability problems.

Key words: Trunk-hip strengthening, Pelvic tilt, Cerebral palsy

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INTRODUCTION

Cerebral palsy (CP) is a chronic neurologic disorder caused by a static lesion in the immature brain and is characterized by deficits in movements and postural control. Because of various muscle function impairments such as weakness, spasticity, incoordination, and reduced selective motor control, many children with CP have difficulties with activities such as propelling their wheelchairs, walking independently, negotiating steps on uneven terrain and running¹⁾. An important treatment goal of therapeutic interventions for children with CP is to improve their ability to walk or perform other functional activities. Most interventions aiming to improve movement abilities in children with CP focus on muscle strength or skeletal alignment which is only a secondary impairment²⁾. Strength training used to be avoided in children with CP because it could lead to increased spasticity and reduced range of motion^{3, 4)}. However, systematic reviews provide reasonable and sufficient evidences that

muscle strength training improves functional motor activity as well as strength in children with CP without adversely affecting spasticity or range of motion^{1, 5)}.

However, in recent years, rehabilitation interventions have focused on promoting muscle strength^{6–8)}. Several studies provide evidences supporting the benefits of strengthening programs in children with CP^{4, 9, 10)}. Damiano et al. found that children with CP exhibit significantly improved quadriceps and knee extensor strength as a result of muscle strength training. They also observed an improved gait pattern in children with CP, such as decreased knee flexion during the stance phase and increased stride length during gait¹¹⁾. In addition, Eagleton et al. report that a 6-week strengthening program in adolescents with CP increased distance walked in 3 minutes, gait velocity, step length, and cadence⁹⁾.

The deviation of pelvic alignment in the standing position is a common problem in children with CP. Such children retain an anterior pelvic tilt due to the contracture of the iliopsoas muscle as well as weakness in the trunk flexors and hip extensors. Problems associated with anterior pelvic tilt include femoral antetorsion and medial shift of the patella to the sagittal plane bisection of the knee joint. Therefore, a major goal of movement training is reciprocal control of the pelvis by improving interplay among the abdominal obliques, rectus abdominalis, quadrates lumborum and lumbar extensor muscles¹²⁾.

On the basis of previous studies, we hypothesized that

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strengthening the trunk and hip muscles increases the muscle activation of the trunk and hips, and decreases the exaggerated anterior pelvic tilt during quiet standing in children with spastic diplegia. Accordingly, we designed modified trunk-hip strengthening exercises based on the core strength exercise for adults and tailored to children¹³. The muscle activation patterns of the four exercises used in this study were analyzed from the electromyography signal, which have been reported previously^{8, 9, 11, 13}. Thus, this study evaluated the effects of trunk-hip strengthening exercise on trunk-hip activation and pelvic tilt motion during standing in children with spastic diplegia and compared the modified trunk-hip strengthening exercise with the conventional exercise with respect to the improvement of pelvic tilt.

SUBJECTS AND METHODS

Ten ambulatory children with spastic diplegia were recruited from Bobath Children's Hospital in South Korea and pre-selected by a pediatric physical therapist. The inclusion criteria were as follows: spastic CP diagnosis, Gross Motor Function Classification System (GMFCS) level I, age between 6 and 13 years, able to understand and follow verbal instructions, and able to participate in a group training program. The exclusion criteria were as follows: unstable seizures, any treatment for spasticity or surgical procedures up to 3 months (for botulinum toxin injections) or up to 6 months (for orthopedic surgery) prior to the study, and any change in spasmolytic medication expected during the study period. The physical characteristics of the subjects are presented in Table 1. All the participants understood the purpose of this study and provided written informed consent prior to participation in accordance with the ethical standards of the Declaration of Helsinki.

Each child participated three 30-minutes one-on-one sessions with a physical therapist per week for 6 weeks. The conventional trunk-hip strengthening exercise group received routine physiotherapy for 15 minutes and conventional trunk-hip strengthening exercise for 15 minutes. The exercise consisted of a bridge exercise and a modified quadruped position with lower extremity lift. Meanwhile, the modified trunk-hip strengthening exercise group received routine physiotherapy for 15 minutes and modified trunk-hip strengthening exercise for 15 minutes. The newly designed exercise consisted of modified unilateral bridge exercise and modified prone bridge exercise (Fig. 1).

To measure the participants' muscle activation, bipolar surface EMG (WEMG-8, LAXTHA, South Korea) data from 5 muscles (listed below) were used. Before attaching the electrodes, the skin was carefully shaved, rubbed, and cleaned with alcohol. The 5 sites on the dominant side were as follows: (1) the rectus abdominis (RA) muscle at the level of the anterior superior iliac spine, 1–2 cm lateral to the midline; (2) the erector spinae (ES) muscles, 1–2 finger widths lateral from the L1 spinous process; (3) the gluteus maximus (GM) muscle, 50% of the distance from sacral vertebrae to the greater trochanter at the greatest prominence of the middle buttocks parallel to a line from the posterior superior iliac spine to the middle posterior thigh; (4) the rectus femoris (RF) muscle, 50% of the distance from the

Table 1. Physical characteristics of the participants ($N = 10$)

Variable	Conventional group	Modified group
Age (years)	8.2 ± 0.8 (7–9)	8.2 ± 1.6 (6–10)
Height (cm)	119.4 ± 9.7 (110–133)	119.8 ± 11.4 (109–134)
Weight (kg)	21.2 ± 3.5 (17–26)	21.4 ± 5.6 (18–31)
Gender (females/males)	3/2	3/2

Data are mean ± SD (range)

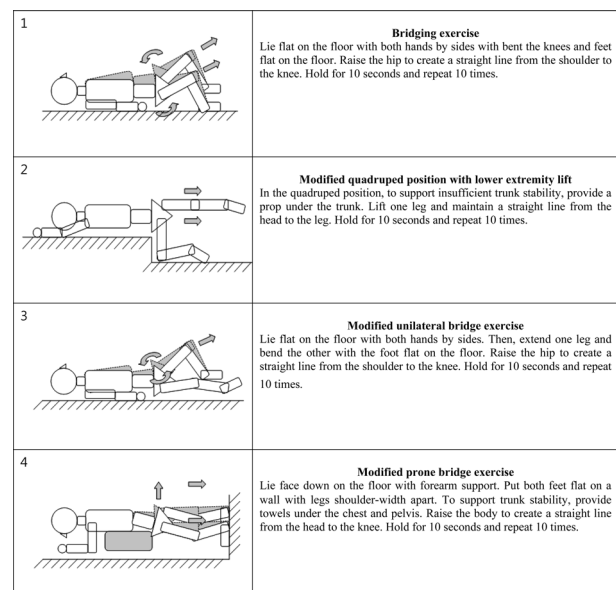


Fig. 1. Schematics and descriptions of the conventional (1, 2) and modified (3, 4) trunk-hip strengthening exercises

anterior superior iliac spine to the superior patella; and (5) the semitendinosus (ST) muscle, 50% of the distance from the ischial tuberosity to the medial tibial epicondyle. The reference electrode was placed on the pectoralis major muscle. The EMG signals were preamplified, filtered (input impedance, $10^{12} \Omega$; common mode rejection ratio, 110 dB; bandpass digital filter, 50–300 Hz) and sampled at 1,024 Hz. The raw EMG data were converted into root mean square data using TeleScan version 3.3 (LAXTHA, Daejeon, South Korea).

Pelvic tilt angle was evaluated by using a Dualer IQ inclinometer (JTECH Medical, Midvale, USA). The primary sensor was placed on T12 and the secondary sensor was placed over the sacral midpoint in the sagittal plane; we recorded the angle with the participant standing in the neutral position, with knees straight, and weight equally on both feet.

Data analysis was performed using SPSS 19.0 (SPSS Inc., Chicago, USA). The level of significance was set at $p < 0.05$. Data are expressed as mean ± standard deviation. The Wilcoxon signed rank test was used to analyze the differences in EMG data and pelvic tilt motion before and after the intervention. The significance of differences between the conventional and modified groups was evaluated by the

Table 2. Changes in pelvic tilt angle and muscle activation over 6 weeks

Variables	Conventional strengthening group			Modified strengthening group		
	Pre	Post	Change	Pre	Post	Change
Angle (°)	24.2 ± 5.8	19.0 ± 7.2	-5.2 ± 3.9	26.8 ± 5.5	18.8 ± 3.5*	-8.0 ± 4.0
RA	5.8 ± 1.4	6.1 ± 3.4	0.3 ± 2.5	7.9 ± 3.7	4.9 ± 1.6	-3.0 ± 3.6
ES	13.6 ± 8.1	13.9 ± 6.9	0.2 ± 8.0	25.0 ± 15.1	15.0 ± 7.8*	-10.0 ± 7.7*
GM	7.3 ± 5.8	7.8 ± 7.5	0.5 ± 2.5	4.2 ± 1.4	4.6 ± 2.3	0.4 ± 1.9
RF	15.6 ± 8.5	12.9 ± 6.4	-2.7 ± 4.6	7.8 ± 4.3	5.3 ± 3.6*	-2.5 ± 1.4
ST	15.0 ± 10.3	7.7 ± 1.5	-7.1 ± 11.3	31.9 ± 18.0	15.7 ± 5.0*	-16.2 ± 15.0

Data are mean ± SD. * $p < 0.05$.

Pre: pre-intervention, Post: post-intervention, RA: rectus abdominis, ES: extensor spinae, GM: gluteus maximus, RF: rectus femoris, ST: semitendinosus

Mann-Whitney U-test (Table 2).

RESULTS

The anterior pelvic tilt angle during standing decreased significantly in the modified group after 6 weeks of training ($p < 0.05$). However, no significant change was observed in the conventional group. There was no significant difference in the anterior pelvic tilt angle between groups ($p < 0.05$).

ES, RF, and ST activation during standing decreased significantly in the modified group after 6 weeks of training ($p < 0.05$), but no significant changes were observed in RA or GM activation. Furthermore, there were no significant changes in the activation of any muscle in the conventional group after 6 weeks of training.

Meanwhile, only the activation of the ES differed significantly between groups ($p < 0.05$).

DISCUSSION

This study evaluated the effects of modified trunk-hip strengthening exercise on trunk-hip muscle activation and pelvic tilt motion during standing in children with spastic diplegia and compared the modified trunk-hip strengthening exercise with conventional exercise with respect to the improvement of pelvic tilt. The results show that pelvic anterior tilt during standing decreased after 6-week interventions in both the modified and conventional exercise groups, but only the modified exercise group decreased significantly.

Pelvic position during activities performed in a closed kinematic chain depends on the integrity of the osteoligamentary system, the adequate interaction between muscles and fascia, appropriate neuromuscular control, and anatomically remote factors such as the alignment of the lower-limbs joints¹⁴⁻¹⁶. In particular, anterior pelvic tilt is performed by active force-coupling between the hip flexors and low-back extensors. In contrast, children with CP exhibit passive anterior pelvic tilt owing to contracture of the iliopsoas muscle and weakness of the trunk flexors and hip extensors¹². Therefore, pelvic tilt exercises for children with CP should enhance the strength of these muscles, especially the force-coupling generation between the trunk flexors (i.e., RA and obliquus externus abdominis) and hip extensors (i.e., GM and hamstrings)¹⁷. The significant decrease in pelvic anterior

or tilt during standing after the 6-week intervention could be due to increased activation of the hip extensors and diminished activation of the hip flexors. The EMG results showed significant decreases in the activations of the ES, RF, and ST muscles and a significant increase in GM activation in the modified exercise group. Therefore, the modified trunk-hip strengthening exercise appeared diminish excessive the hip flexor activation and increase hip extensor activation, albeit in a limited manner.

Decreased ES activation is another reason for the significant change in pelvic tilt in the modified exercise group. This result is consistent with previous studies showing lower ES activation after a modified trunk-hip strengthening exercise (i.e., modified unilateral bridging and modified prone bridging) compared to conventional exercise (i.e., bridging and modified crawling position)¹⁸. It is hypothesized that anterior pelvic tilt is linearly associated with a force-coupling between the hip flexors and low-back extensor muscles. The present results suggest the modified trunk-hip strengthening exercise would produce a greater improvement in pelvic tilt motion during standing with diminished activation of the hip flexors and back extensors as well as increased activation of the hip extensors and trunk flexors.

In general, the contraction of "antigravity" muscles is primarily responsible for maintaining the body in an upright position both in both static and dynamic postures. The hip, knee, trunk, and neck extensors are considered major antigravity muscles. Other related muscles include the neck flexors and lateral benders, trunk flexors and lateral benders, hip abductors and adductors, and ankle pronators and supinators¹⁷. Therefore, the present results indicate our exercise program is effective for strengthening the muscles required for standing.

Even highly functional children with spastic CP are likely to have considerable weakness in their involved extremities compared to age-related peers, with the degree of weakness increasing with the level of neurologic involvement. Such weakness limits functional performance in children with CP but can be improved through training. In addition, therapists should be more proactively involved in the prevention of secondary impairments as well as the promotion of wellness and fitness in their patients. Strength and endurance training are important components of fitness, and may improve health throughout life and increase participation in recreational,

social, and occupational activities in children and adults with CP¹⁹⁾. Several recent studies of a more specific group of children with reported standing ability problems suggest more individually tailored exercises could be improved by emphasizing the training of the weakest muscle groups^{4, 8)}. On the basis of the present results, the modified trunk-hip strengthening exercise could be used for specific muscles or muscle groups to improve the standing posture of children with CP.

This study has several limitations that should be discussed. One limitation is the short intervention period for the strength training program. Six weeks is reported to be the minimum time required to observe increases in the strength of adults. However, Eagleton et al.⁹⁾ suggest a similar or greater period is required for children or adolescents with CP. Another limitation of the present study is its small sample size. Finally, the participants were from a specific region around Bobath Children's Hospital in South Korea.

In conclusion, our modified trunk-hip strengthening exercise is more effective for improving trunk-hip activation and decreasing anterior pelvic tilt motion during standing in children with spastic diplegia than the conventional trunk-hip strengthening exercise. Therefore, we suggest using individually tailored modified trunk-hip strengthening exercise programs like the one described herein to strengthen the weakest muscle groups of children with reported standing ability problems.

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