The Effect of Trunk Stabilization Exercises Accompanied by Deep Neck Flexor Strengthening Exercises on the Sitting Balance and Head Alignment of Children with Spastic Diplegia

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Purpose The purpose of the study is to investigate the effect of trunk stabilization exercises accompanied by deep neck flexor strengthening exercises on sitting balance and head alignment of children with spastic diplegia. ***Methods*** Ten children diagnosed with spastic diplegia were randomized. The experimental group (n=5) underwent trunk stabilization exercise paired with deep neck flexor strengthening exercise, and the control group (n=5) underwent only trunk stabilization exercise. The interventions were designed to last 30 minutes a session, and a total of 18 sessions were performed over a period of six weeks. Evaluations were performed twice before and 6weeks after the intervention. The trunk control measurement scale (TCMS), craniovertebral angle were used to compare the effects of exercise methods. ***Results*** There was a statistically significant difference due to an increase in the mean value in the sitting posture balance and alignment between the experimental and control group ($p<0.05$). ***Conclusion*** Trunk stabilization exercise accompanied by deep neck flexor strengthening exercise may be an effective intervention for enhancing sitting posture balance and alignment, upper extremities function of children with spastic diplegia and thus should be utilized more in clinical practice.

Key Words Spastic diplegia, Balance, Alignment, Deep neck flexors, Trunk stabilization

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Received date 27 Jan 2022
Revised date 06 Feb 2022
Accept date 11 Feb 2022

Ⅰ. Introduction

Cerebral palsy refers to a disease that non-progressive damages during the growth and development of the brain cause permanent damages to the movement and posture development, resulting in the limitation of activities and that is accompanied by secondary musculoskeletal problems.[1)] Spastic diplegic cerebral palsy, the most common type of cerebral palsy, can be induced by periventricular leukomalacia due to premature birth.[2)] In periventricular leukomalacia, the legs have more severe motor disorder rather than the arms due to the necrosis of the white matter region proximal to the periventricular region, in which lower extremities become hypertonic while the neck and the trunk become hypotonic.[3)] The hypotonia in the neck and trunk makes children with cerebral palsy hard for anti-gravity movement, further causing delayed neck righting reactions and asymmetric muscle developments.[4)]

As for asymmetric muscle developments of children with cerebral palsy, superficial neck muscles including sternocleidomastoid muscles and suboccipital muscles are shortened; deep neck flexor muscles including longus capitis muscles and longus colli are weakened; and the upper cervical spine is excessively extended while the lower cervical spine is bent, causing forward head posture.[5,6)] Such abnormal neck and head postures also affect the development of thoracic and lumbar muscles and cause imbalanced developments of trunk stabilizer muscles, so that the children are unable to erect the spine while sitting in a slumped posture.[7)] The forward head posture and slumped sitting position of children with cerebral palsy causes the weight biased toward the sacrum instead of both

http:dx.doi.org/10.17817/2022.02.06.1111715

ischiatic tuberosities, inducing the weight support surface to narrow, which makes children with cerebral palsy feel more uncomfortable in posture control.

Children with cerebral palsy that feel uncomfortable in posture control tend to hunch their shoulders toward, limit the degree of freedom in the joints of the upper limbs, and hold the support surface with the hands to protect the unstable trunk instead of using the hands for function in the space.[8] Children with cerebral palsy who are unable to use their hands for function in the space have fewer opportunities to receive various sensory information from surroundings or through experiences so they are prone to have limitations in explorative activities, plays, daily activities, and school life.[9]

For posture alignment and improvement in physical functions, children with cerebral palsy need to have opportunities for normal movements by improving head alignment and trunk stability.[10] Trunk stability exercises can improve balance performance and arm functions of children with cerebral palsy who are unable to freely use the arms due to posture instability. Regarding trunk stability exercise, it is recently greatly emphasized on the roles of deep neck flexor muscles including longus colli and longus capitis muscles that support the head for balance maintenance of the whole body among the head, neck, back, and lower back and provide stability.[11,12] Also among the therapeutic exercises, the neck stabilization exercise, which strengthens the deep muscles of the neck, which plays a leading role in maintaining the stability of the spine, and induces the cervical vertebrae to be positioned in a neutral position, is attracting attention.[13] Functional improvements in a part of the body positively influence functional improvements of the other parts.[14] The sway of the head in children with cerebral palsy correlates with trunk instability, and deep neck flexor muscle strengthening exercise leads to the activation of abdominal muscles.

Previous studies on children with cerebral palsy emphasized muscle activity and strength enhancement through deep neck flexor strengthening exercises or trunk stabilizaton exercises, respectively. Thus, the present study applied trunk stability exercise accompanied by deep neck flexor muscle strengthening exercise and investigated changes in the balance in sitting position and the head alignment, by which this study was intended to provide fundamental data for the intervention against cerebral palsy.

II. Material and Methods

1. Subjects

The subjects of the present study were children who were visiting M hospital located in B city and were diagnosed with spastic paraplegia diagnosis. Of them, 10 children were selected who voluntarily participated after an explanation about the procedure and purposes of the study was given both to subjects and guardians. After all the subjects and legal guardians were given a full explanation about the procedure and purposes of this study, the subjects voluntarily participated in the present study. The inclusion criteria of the present study for subjects were as follows: Level 3 or lower in the gross motor function classification system (GMFCS); possible to perform independent sitting; G2 or lower in the modified ashworth scale (MAS) for lower extremity spasticity; and possible for free communication with Level 8 in the Rancho Los Amigos. All children had no orthopedic surgery, no convulsion within the past 6 months, and no botulinum toxin injection.

2. Procedure and intervention of the study

10 children with spastic diplegia were randomly matching pair assigned either to the experimental group or to the control group with 5 for each group. All subjects had 30 min of stability exercise for each session, three sessions per week for a total of 6 weeks. Based on preceding studies,[15] the exercise program was composed of 5 min of warming-up, 20 min of the main exercise, and 5 min of warm-down. In the main exercise, a pressure biofeedback (Stabilizer TM, Chattanooga Group Inc., Hixon. USA) was put at the back of the head of children in the experimental group during trunk stability exercise, enabling them to have deep neck flexor muscle

strengthening exercise while having visual-tactile sensory feedback. On the contrary, the control group had a general trunk stability exercise (Table 1). The exercise intervention was applied within the range that showed no signs of high muscle tension, such as bending toes, holding the fist, and pulling back the lip and tongue. During trunk stability exercise, children were counting the number for natural breathing. If children complained of pain or tiredness during the exercise, we immediately stopped them to have a rest. One physical therapist with 4 years of physical therapy experience performed the intervention and evaluation. The evaluation was performed total 2 time before and after the intervention in order to examine balance ability and craniovertebral angle in sitting position. The present study was approved by the institutional review board of K University in B city (the approval number: KSU-19-08-004).

3. Outcome measure

1) Trunk control measurement

To measure balance ability in sitting position, the trunk control measurement (TCMS) was used. The TCMS is an evaluation tool that is appropriate for testing balance ability in the sitting position of spastic children with cerebral palsy who can perform independent sitting. The TCMS is composed of a total of 15 items, including 5 items for static sitting balance ability, 7 items for dynamic sitting balance ability, and 3 items for dynamic fetching (static reaction), which were scored between 0 to 58 points. A higher score meant a better ability in trunk control.[16] For measurements, children were instructed to sit on a treatment table that has neither back support, armrest, nor footrest, with taking off socks, orthoses, and shoes, and then put both hands on the legs while maintaining both hip and knee joints at 90 degrees. After three measurements, the mean value was used as the representative value. The (inter-) reliability among measuring researchers of the TCMS was r=0.98, and the (intra-) reliability within measuring researchers was r=0.97.[17]

2) Craniovertebral angle

To evaluate the head alignment of children with cerebral palsy in sitting position, the Image J analysis program (Sun Microsystems, Inc, USA) was used to analyze craniovertebral angles. Image J allows statistical analyses of distances, angle areas, pixel values, spatial measurements, and concentrations in images as well as general image processing.[18,19] The (inter-) reliability among measuring researchers was r=0.97, and the (intra-) reliability within measuring researchers was r=0.88-0.98.[20] Images for the analysis of craniovertebral angle were taken with setting up a camera 3 m away from the subject and 1.2 m high above the

Table 1. Intervention program

Exercise type	Experiment group (n=5)	Control group (n=5)	Time
Warm-up	Stretching	Stretching	5min
Exercise	Deep neck flexor muscle strengthening exercise accompanied trunk stabilization exercise	Trunk stabilization exercise	20 min
	Deep neck flexor muscle strengthening exercise accompanied abdominal pull 1	Abdominal pull exercise	
	Deep neck flexor muscle strengthening exercise accompanied abdominal pull 2		
	Deep neck flexor muscle strengthening exercise accompanied bridge exercise	Bridge exercise	
	Deep neck flexor muscle strengthening exercise accompanied sit-up exercise	Sit-up exercise	
Warm-down	Breathing exercise	Breathing exercise	5 min

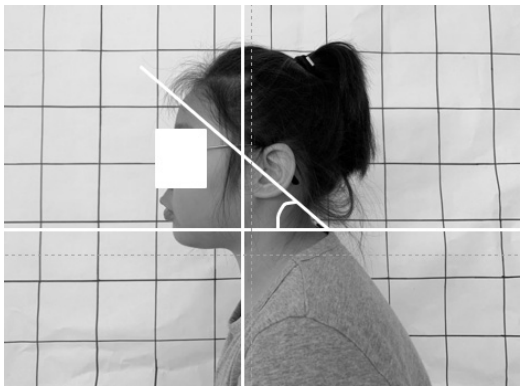

Figure 1. Craniovertebral angle

floor. Subjects were instructed to sit on a chair with back support in a comfortable posture, in which the angle between the hip joint and the knee joint was made 90° while the sole touching the floor, and the hands were naturally placed on the knee. They were also instructed to make natural head position in self-balancing posture, and keep staring at their own eyes in the mirror placed in front of them. The craniovertebral angle was defined as the angle between the horizontal line and the line connecting the ear tragus and the spinous process of the C7 vertebra, in which the craniovertebral angle decreased as forward head posture became severe (Figure 1).

4. Statistical analysis

The general characteristics of subjects were analyzed by descriptive statistics. In addition, covariance analysis was used to examine the difference between the experimental group and the control group depending on the exercise method considering the measurement values before intervention. SPSS 23.0 was used as a statistics program, and the significance level (α) was set to 0.05.

III. Results

1. General characteristic of the subjects

The general characteristics of subjects were summarized (Table 2). The experimental group was composed of 2 males and 3 females, and they had

Table 2. General characteristics of subjects

Characteristics		Experimental group(n=5)	Control group(n=5)
Age(years)		8.69±3.28	7.20±1.92
Height(cm)		122.20±20.13	109.80±11.03
Weight(kg)		28.60±14.63	19.60±5.45
Body mass index		17.93±3.61	15.90±1.29
Gender	Male	3(60%)	1(20%)
	Female	2(40%)	4(80%)
GMFCS level	Ⅰ	2(40%)	1(20%)
	Ⅱ	2(40%)	2(40%)
	Ⅲ	1(20%)	2(40%)

M±SD: Mean±standard deviation
GMFCS: Gross motor function classification system

8.69±3.2 years of mean age, 122.20±20.13 cm in mean height, 28.60±14.63 kg in mean weight, and 17.93±3.61 in mean BMI. In the gross motor function classification system, there were 2 subjects in Level 1, 2 in Level 2, and 1 in Level 3. The control group was composed of 1 male and 4 females, and they had 7.20±1.92 years of mean age, 109.80±11.03 cm in mean height, 19.60±5.45 kg in mean weight, and 15.90±1.29 in mean BMI. Regarding the gross motor function classification system, there were 1 subject in Level 1, 2 in Level 2, and 2 in Level 3.

2. Comparison of balance in sitting position and craniovertebral angle depending on exercise method

The experimental group that had trunk stability exercise accompanied by deep neck flexor muscle strengthening exercise was compared with the control group in terms of the effect of trunk stability exercise on balance ability in sitting position and craniovertebral angle (Table 3).

Mean balance scores in sitting position before the intervention were 29.60 points for the experimental group and 20.80 points for the control group, while the scores were 42.80 points for the experimental group and 27.20 points for the control group after the intervention, showing the mean values increased ($p<0.05$). Covariance analysis was performed consider-

Table 3. Comparison of balance in sitting position score and craniovertebral angle depending on exercise method

	Experimental group(n=5)		Control group(n=5)		F	P
	Pre	Post	Pre	Post		
TCMS	29.60±15.40	42.80±10.08	20.80±4.32	27.20±5.76	3.19	0.00*
CVA	41.31±10.55	53.39±5.89	36.69±5.39	41.47±4.64	4.62	0.01*

Mean±SD,
*P<0.05
TCMS: Trunk control measurement scale; CVA: Craniovertebral angle

ing the measurement values of balance ability in sitting position before the intervention, which found a statistically significant difference between the experimental group and the control group depending on exercise method (p<0.05).

Craniovertebral angles were 41.31° for the experimental group and 36.69° for the control group before the intervention, while they were 53.39° for the experimental group and 41.47° for the control group after the intervention, showing that the mean degree increased (p<0.05). Covariance analysis considering the measurement values of alignment in sitting position before intervention found that the experimental group and the control group had a statistically significant difference depending on the exercise method (p<0.05).

Ⅳ. Discussion

The present study investigated the effect of trunk stability exercise accompanied by deep neck flexor muscle strengthening exercise on the balance and head alignment in the sitting position of children with cerebral palsy. Trunk stability exercise accompanied by deep neck flexor muscle strengthening exercise is an exercise that considers interconnectivity and complementarities of the head, neck, and trunk, which have positive effects on the maintenance of correct alignments between the head and the spine, and the improvement of function, posture control, and balance ability of children with cerebral palsy.[21)]

When the body establishes the basis for the surroundings and controls posture, the head and the neck provide stable supporting bases for the visual system and the vestibular system. Vision is greatly affected by head stability, in which visual-perceived information processing ability is promoted as the head stability increases[22)] In children with cerebral palsy, the visual information processing, trunk control, and balance ability also can be changed depending on the head stability.[23)] In a study with children with spastic diplegia, the exercise group that applied strengthening exercises of both deep neck flexor muscle and trunk muscle showed positive effects on trunk control ability in comparison to the control group.[24)] Shin (2016) also reported that the exercise group combined with neck stabilization exercise and trunk stabilization exercise showed improvement in balance ability compared to the control group for children with spastic biceps paralysis.[25)] In the present study, the experimental group that had trunk stability exercise intervention accompanied by deep neck flexor muscle exercise also showed more improvement of balance control ability in sitting position than the control group only with general trunk stability exercise, which was consistent with the preceding study. Such results seemed that the improved head stability of children with cerebral palsy affected visual information processing, leading to the improvement of trunk stability and balance control. The longus capitis muscle and longus colli that are deep neck flexor muscles support the head and the neck to maintain the correct posture during the movement of the head in diverse directions, helping the maintenance of the whole balance and stability of the body.[26)]

Once the longus capitis muscle and longus colli are weakened, the control ability of neck muscles is declined, which leads to the excessive extension of the upper cervical spine, while the flexion of the low-

er cervical spine, resulting in the forward head posture that the head leans forward.[27] Neck stability exercise that induces head-neck flexion to strengthen deep neck flexor muscles including the longus capitis muscle and longus colli is effective for strengthening the strength and endurance of deep neck flexor muscles and improving forward head posture.[28] Neck stability exercise of children with cerebral palsy induces the micro-control for the activation and movement of deep neck flexor muscles that are important for posture maintenance, leading to an improvement of posture alignment and motion control. Consistently, the present study also found that the experimental group with trunk control exercise accompanied by deep neck flexor muscle strengthening exercise had a more improvement in craniovertebral angle than the control group only with general trunk stability exercise, indicating that the head alignment of children with cerebral palsy was positively improved. It seemed that trunk stability exercise accompanied by deep neck flexor muscle strengthening exercise helped the maintenance of correct alignment of the cervical spine, resulting in a higher craniovertebral angle, and an improvement in head control and alignment. Taken together, these results suggest that trunk stability exercise accompanied by deep neck flexor muscle strengthening exercise had be an effective intervention to improve the balance in sitting position and the head alignment of spastic paraplegia children. So that this intervention should be actively used in clinical practice for the improvement of balance and head alignment of children with cerebral palsy.

The present study has the following limitations. Since the number of subjects is not enough to generalize the results of the present study to all age groups of children with cerebral palsy in various functional levels. In addition, there was no follow-up study, so the continuity of the intervention was unable to be tested. Therefore, it should be further studied with children with cerebral palsy in various age groups and functional levels to complement such limitations and it should be also investigated on the continuity of the effect of deep neck flexor muscle strengthening exercise

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