



Electromyographic Evaluation of Breathing-based Neck Training in Children with Cerebral Palsy

Hwa-Kyung Shin^{1,*} and Sung-Kyung Choi²

Abstract

This research aimed to evaluate the effects of Breathing-Based Neck Movement Training (BBNMT) on neck and trunk muscle activation during speech in children with Spastic Cerebral Palsy (SCP). Sixteen children with SCP (eight training, eight controls) participated in this study. The BBNMT consisted of 30 min of training and 15 sessions over 5 weeks. BBNMT consisted of head-neck flexion, neck rotation, lateral flexion, and neck extension. The control group did not perform any additional program. We performed electromyography for neck and trunk muscle activity: Upper Trapezius (UT), Sternocleidomastoid (SCM), and Rectus Abdominis (RA). Children sat comfortably and were instructed to pronounce a vowel [a:] as long as possible. EMG analysis showed that muscle activation significantly differed between test sessions and between muscle types ($p < 0.05$). Additionally, it significantly differed in the interaction of test sessions and muscle type ($p < 0.05$). In the post-hoc test, UT and the SCM were significantly lesser in the post-test and follow-up than in the pre-test ($p < 0.05$), and RA was significantly greater in the post-test and follow-up than in the pre-test ($p < 0.05$). RA was significantly lesser than UT and SCM in all test sessions ($p < 0.05$).

Keywords: Breathing; Cerebral palsy; Electromyogram; Neck; Speech.

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1. Introduction

Cerebral palsy (CP) is a non-progressive lesion in brain tissue during the fetal or infant period. Spastic CP causes permanent impairment in the growth of posture and movement, with disturbance in voice and speech.^[1] Speech-motor involvement, including dysarthria, is present in more than half of children with spastic CP. Injury in speech subsystems, such as articulation, breathing, phonation, and resonance, is included. Additionally, excessive drooling and facial asymmetry can be detected at rest, through speaking, or while feeding.^[2] Speech deficiencies affecting all speech subsystems to varied degrees are common in CP speakers. General subjects like body placement, neurodevelopment treatment, and muscle weakness and incoordination should be considered by speech-language pathologists.

The development of speech depends on speech breathing.^[2] It refers to the respiratory processes that produce and sustain subglottal air pressure during speech production as

well as the inhalation that occurs before to speaking.^[3] To support speech, the respiratory system's active and passive muscle tension must be regulated. It induces respiratory kinematic movement of the rib cage and diaphragm by the action of the intercostal and muscles in abdomen in typically developing children.^[3] In particular, the normal development of the head and neck is one of the fundamental biomechanical factors for the motor development of other body parts.^[4] Impaired movement of the head and neck may affect speech-motor development.

Children with spastic CP lack postural stability with a low neck and trunk muscle tone.^[5] This results in compensatory hypertonicity of the arms and legs around the neck and trunk to maintain posture or perform function.^[5] Spasticity of the chest wall also results in reduced chest mobility. The same might make it harder to use passive recoil pressure when producing speech and to start talking at larger lung volumes. Abnormal breathing patterns make it difficult to control inspiration and expiration during speech production.^[6] Uncontrolled breathing may induce an irregular pattern in frequency and length.^[7] Thus, breathing and speaking may be temporarily inhibited because of insufficient airflow during speech production. Dysfunction of the laryngeal muscles results in explosive sounds and forced speech, which generally

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leads to the production of a high and drooping pitch. Some studies reported clinical strategies to improve speech breathing, which included Biofeedback, speech-guided breathing retraining, LSVT (Lee Silverman Voice Treatment), Glossopharyngeal breathing, unilateral forced Nostril breathing, and expiratory muscle training.^[8] Typically, treatment plans focused on increasing vocal loudness, speech rate, or a mix of rigorous therapy modalities. As a result, there were gains in overall intelligibility, articulatory accuracy, and voice quality.^[9,10] Proper body alignment and posture may induce correct respiratory kinematics for speech breathing. Speech breathing, *i.e.*, breathing during speech production, has been previously studied in Children with spastic CP.^[11] Although the importance of general postural control has been commonly mentioned in previous studies on physical therapy for CP children, few studies have focused on speech breathing or speech therapy.

CP children often have an unstable sitting posture, with their head chin out with posteriorly rotated and forward head posture and exhibit lumbar kyphosis and pelvic posterior tilt due to weakness in the trunk muscles. Moreover, SCM and UT are overactive due to the abnormal overuse of inspiratory accessory muscles during breathing. Therefore, this study aimed to analyze the effects of BBNT on neck and trunk muscle activation during speech in children with spastic cerebral palsy using electromyographic evaluation.

2. Methods

2.1 Subjects

This study recruited 16 children with SCP (8 training, 8 controls). The selection criteria for subjects included medical diagnosis with diplegic SCP, independent sitting, GMFCS levels III and IV, no respiratory diseases, no speech therapy, and mental capacity to comprehend and adhere to the researcher's directions. Following a thorough explanation of the study, the children and their guardians who participated in it provided written informed permission. Table 1 displays the subjects' overall characteristics. The Institutional Review Board (IRB) of Daegu Catholic University approved this study (CUIRB-2019-0043).

Table 1: Subjects' general qualities.

	Training (n=8)	Control (n=8)
Gender (M/F)	6/2	5/3
Age (years)	6.13±2.53	6.53±1.43
Height (cm)	114.38±13.51	119.12±12.29
Weight (kg)	23.38±7.09	23.89±10.79
GMFCS (III/IV)	3/5	4/4

2.2 Experimental design

We conducted EMG measurements to examine the effect of BBNT for five weeks. The training group performed three test

sessions of EMG measurement: pre-test, post-test, and follow-up two weeks after completing training. The control group performed two measurements: pre-test and post-test. Three muscles were measured: Upper Trapezius (UT) muscles, Sternocleidomastoid (SCM) muscles, and Rectus Abdominis (RA).

The same examiners and environment were maintained, and a triple-blinding (examiner, therapist, participants) approach was adopted to increase reliability.

2.3 Breathing-based neck training

The Breathing-based Neck Training (BBNT) consisted of four exercises: head-neck flexion, neck rotation, neck lateral flexion, and head-neck extension (Fig. 1). Our intervention was performed for thirty minutes, three sessions a week, fifteen sessions for five weeks. One session consisted of ten repetitions, five with no resistance and five with moderate resistance. Three minutes of rest were provided between sessions. The therapist instructed the children to inhale in the starting position and then forcefully exhale with the abdominal muscle contraction while moving to the end position with prolonged phonation of the vowel /a:/. There were no extra stability training exercises for the control group.

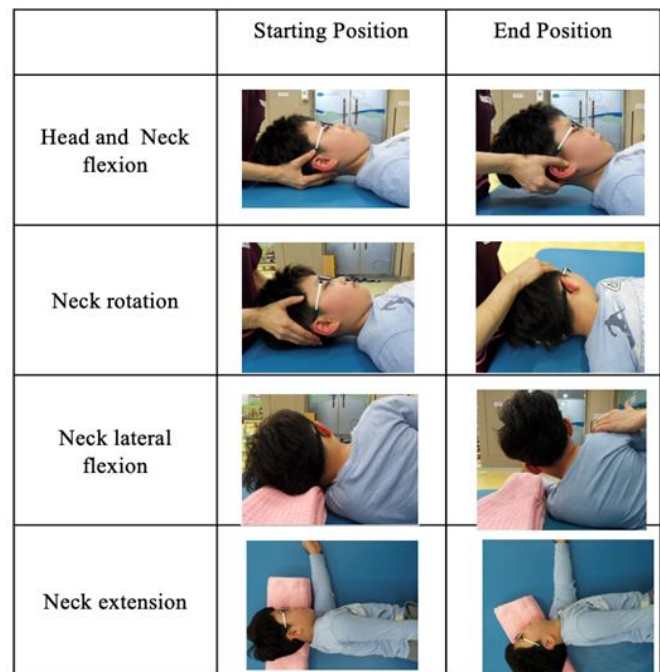


Fig. 1: Head-neck exercise with forced inspiration.

2.3.1 Head and neck flexion

The arms were parallel to the trunk with elbow extension in the supine position, and the head was neutral. The therapist's hand applies downward pressure to the thorax to stabilize Children with weak abdominals. Following inspiration in the initial position, the kids were told to flex their necks while maintaining a lowered chin. Forced expiration was performed with contraction of the expiratory abdominal muscle during head-neck movement. Resistance was applied to the forehead,

and the resistance direction was head and neck extension.

2.3.2 Neck rotation

The arms were parallel to the trunk with elbow extension in supine, and the head was neutral. Children were directed to rotate their heads to the right side of the possible range after being inspired in the starting position. They were then instructed to return to the midline. They inhaled again, rotated the available range's left side, and then the children returned to the midline. The temporal region of the head was subjected to resistance, with ipsilateral rotation serving as the resistance direction.

2.3.3 Neck lateral flexion

Children started neck lateral flexion in a side-lying. The therapist placed a towel under the temporal region to ensure the head and spine remained straight. After inspiration in the starting position, children were trained to flex the head to the right side of the available range. After the children returned to the midline, they inhaled again and then flexed the left side of the available range. Resistance was applied on the temporal region of the head, and the resistance direction was an ipsilateral extension.

2.3.4 Head-neck extension

Children started neck lateral flexion on the side-lying with a towel under the temporal region. After inspiration in the starting position, children were instructed to extend the head-neck to the available range. The children were instructed to look at the top of the head with their eyes so that the neck extension could occur. Resistance was applied just proximal to the occiput, and the resistance direction is flexion of the head-neck.

2.4 Experimental equipment and processing

This study used an 8-channel wireless EMG system (WEMG-8, LXM 5308, Laxtha, Korea) to measure surface EMG (sEMG) signals. To improve conductivity, the electrode placement area was cleaned with an alcohol swab before attaching disposable medical electrodes. The electrodes were assigned to the UT muscles and SCM muscles, which are inspiratory muscles, and the RA muscles, which are expiratory. The UT muscle was attached between the top of a scapula and the middle of the spinous procedure of the seventh cervical vertebra, the SCM muscle was attached at the midpoint between the mastoid procedure and the sternal origin, and the RA muscle was attached about 2 cm away, parallel to the navel. All electrodes were attached parallel to the direction of the muscle fibers of each muscle, and the reference electrode was attached to the flat posterior wrist. The sampling rate was 1024 Hz, the bandpass filter was 10 Hz to 450 Hz, and the notch filter was 60 Hz. The subjects were instructed to face forward while seated on a chair without a backrest. EMG muscle activity during extended phonation of the vowel /a:/ was measured for 10 s in a sitting position. For the analysis of

muscle activity, surface EMG data for 6 s, excluding every 2 s of each of the first and last signals, were analyzed as root mean square (RMS). After that, the mean values of RMS were normalized into % MVIC (maximal voluntary isometric contraction), which was set as the representative value.

2.5 Statistical analysis

SPSS (Statistical Package for the Social Sciences) 21.0 was utilized for analysis. Two-way Repeated measure ANOVA was used to evaluate the effects of the BBNT according to test sessions and muscle types in the control and training group. Turkey was used for the post hoc test. The significance level for the statistical analysis was set at 0.05.

3. Results and discussion

3.1 Results

In the training group, EMG muscle activation significantly differed between test sessions and among muscle types ($p < 0.05$) (Table 2). Additionally, it significantly differed in the interaction of test sessions and muscle type ($p < 0.05$) (Table 2). In the post-hoc test, UT and a SCM were significantly lesser in the post-test and follow-up than in the pre-test ($p < 0.05$), and RA was significantly greater in the post-test and follow-up than in the pre-test ($p < 0.05$). RA was significantly lesser than UT and SCM in all test sessions ($p < 0.05$) (Fig. 2). Further, UT and SCM showed no significant differences from each other in all test sessions ($p > 0.05$) (Fig. 2).

Table 2: ANOVA results for comparing the muscle activation according to test session and muscle type in training group.

ANOVA table	Sum of square	DF	Mean square	F	P
Test Session x Muscle	79	4	20	6.44	0.000
Test Session	167	2	83	27.04	0.000
Muscle	894	2	447	17.83	0.000

In the control group, EMG muscle activation significantly differed among muscle types ($p < 0.05$) (Table 3). However, there was no significant change among the test session ($p > 0.05$) (Table 3) and the interaction of the test session and muscle type ($p > 0.05$) (Table 3). Muscle activation of UT and SCM were significantly higher than that of RA in training group ($p < 0.05$) and control group ($p < 0.05$) (Fig. 3). However, muscle activation of UT and SCM had no significant difference in training group ($p > 0.05$) and control group ($p > 0.05$) (Fig. 3)

3.2 Discussion

For speech-language pathologists and other rehabilitation professionals, managing the communication issues of CP children poses numerous problems. Information regarding breathing, tone imbalance, body alignment, muscle weakness and incoordination, and neurodevelopmental treatment is

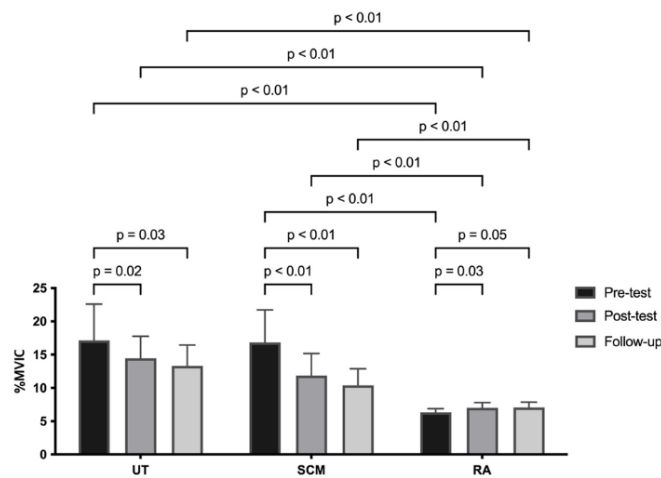


Fig. 2: Comparison of EMG activation between test sessions and muscle types in training group.

UT: upper trapezius, SCM: sternocleidomastoid, RA: rectus abdominis, % MVIC: % maximal voluntary isometric contraction and *p<0.05.

Table 3: ANOVA results for comparing the muscle activation according to test session and muscle type in control group.

ANOVA table	Sum of square	DF	Mean square	F	P
Test Session x Muscle	6.5	2	3.3	0.35	0.710
Test Session	0.64	1	0.64	0.068	0.797
Muscle	1672	2	836	35	0.020

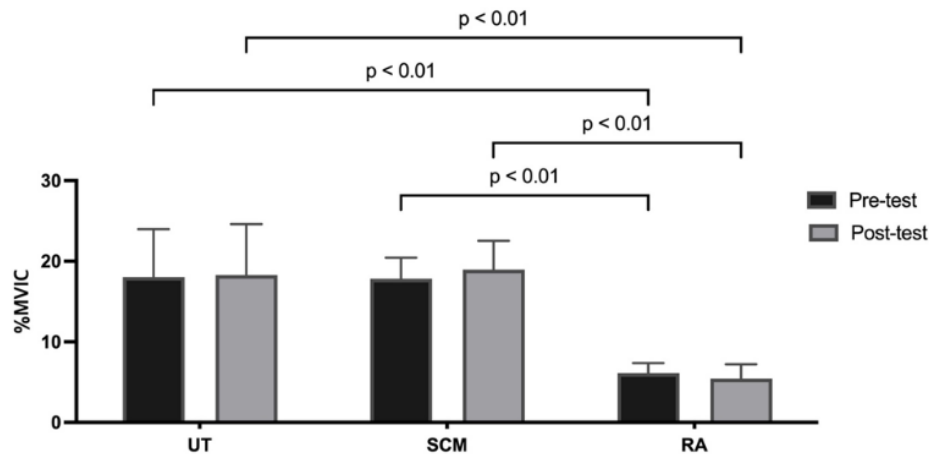


Fig. 3: Comparison of EMG activation between test sessions and muscle types in control group.

UT: upper trapezius, SCM: sternocleidomastoid, RA: rectus abdominis, % MVIC: % maximal voluntary isometric contraction.

required.^[12] Good postural alignment of the head and trunk been reported to improve voice function, enhance the contact of the vocal cords, and help activate the normal inspiratory and expiratory muscles.^[7,13] The voice quality of CP children results from the upright posture of the shoulders, neck, head, and chin.^[8] Shin *et al.* (2015) investigated how children with spastic CP's breathing patterns and maximum phonation might be impacted by an ergonomic method using seat inclination levels.

Children with spastic CP generally have compensatory oral breathing pattern accompanied by neck instability and forward head posture.^[14] Oral breathing is a symptom of a

change in posture and respiration.^[15] Most of them consist of structural adaptation of the head and neck that lead to an increase in the compensatory movement of neck muscles, resulting in a reduction of thoracic expansion of the vital capacity.^[16] They tend to contract strongly the accessory inspiratory muscles, such as the UT and levator scapulae, rather than the neck extensor to support the neck during speech production. Finally, the muscle tone of superficial neck flexors, like the SCM and anterior scalene, increased,^[17] and the tonic-holding movement of the deep neck flexors, such as longus capitis and longus colli, decreased.^[17,18] The decreased muscle activity of SCM and RA and the increased muscle activity of

RA may positively affect muscle coordination for speech breathing in children with spastic CP. The decreased activation in UT and SCM indicates that the compensatory strategy of the inspiratory muscle during speech production was reduced.^[19] Freire *et al.* (2012) reported that the vital capacity and thoracic expansion of patients with oral breathing increased after the static stretching of the sternocleidomastoid, upper trapezius, and pectoralis major. This result is almost consistent with our results.

BBNT may engage the deep abdominal muscles by forced expiration from the starting position to the end since the inspiration occurs at the starting position. For postural stability and trunk stability, the abdominal muscles are crucial. One of the main issues with motor dysfunction in children with spastic CP is poor posture control. To enhance postural control and function, therapists frequently concentrate on trunk control as early as feasible and directly or indirectly target the abdominal muscles. However, it is challenging to increase the activation of abdominal muscles because children with spastic CP exhibit a pattern of abdominal muscle activation is different from typical developing children,

This can be attributed to an inactive abdominal muscle linked with the co-contraction of extremity muscle. It means fixation of the trunk, including with the flexors, adductors, and internal rotators of the hip that occurs in typical postural and gait patterns. This study showed a statistically significant increment in abdominal muscle activity after intervention. In the intervention of the training group, the therapist instructed the child to inhale in the starting position and then forcefully exhale with the contraction of the abdominal muscle while moving to the end position with prolonged phonation of the vowel /a:/. This method made children contract-relax the abdominal muscles themselves. It separated from typical motor recruitments and facilitated the abdominal muscle functionally. Furthermore, we predicted it affected the balance of neck muscles related to breathing speech.

Speech disorders of CP children are classified as dysarthria and paralytic speech disorders.^[1,20] Their voice can be fragile and choking due to weakened breathing. Its features include impaired breathing and vocalization, distortion of consonants and vowels, and lack of speech rate control.^[8] Many aspects of speech sounds are intimately related to respiration. The quality, duration, loudness, and pitch of phonation are all influenced by respiratory function. According to a study on patients with multiple sclerosis, speech therapy and respiratory training techniques, including expiratory muscle strengthening exercises, are necessary to improve phonation quality.

Recent studies have highlighted the impact of physiological and signal processing factors on speech function.^[21,22] A novel speech steganography mechanism utilizing shift-invariant continuous wavelet transform has been developed to optimize speech signal processing and enhance communication efficiency.^[23] Additionally, research has shown a correlation between habitual snoring, middle ear

disease, and speech problems in young children with non-syndromic cleft palate anomalies, emphasizing the intricate relationship between physiological conditions and speech development.^[24] These findings underscore the importance of considering both neurological and physiological factors in speech interventions, aligning with our study's focus on neuromuscular coordination and its role in improving speech breathing efficiency in children with spastic cerebral palsy. However, additional study is needed to evaluate the efficiency of BBNT in aspects of acoustic and aerodynamic measurement.

While this study provides valuable insights through electromyographic analysis, it has limitations. The small sample size restricts the generalizability of the findings, and the study duration was relatively short. A repeated measurement design was employed to mitigate these limitations, including pre-test, post-test, and follow-up assessments. Nevertheless, future research should involve a larger participant pool and extended study periods to validate and expand upon these results.

4. Conclusion

This study demonstrated that BBNT effectively improves the imbalance of neck and trunk muscle activation during speech breathing in children with spastic CP. Electromyographic analysis confirmed significant changes in muscle activation patterns, indicating improved coordination of inspiratory and expiratory muscles. These findings highlight the importance of objective EMG evaluation in assessing intervention outcomes for speech-related motor impairments. BBNT led to enhanced speech breathing efficiency, suggesting that direct physical intervention can normalize muscle imbalances critical for speech production. Further research incorporating multidisciplinary approaches and long-term EMG assessments is needed to validate and expand these findings.

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Conflict of Interest

There is no conflict of interest.

Supporting Information

Not applicable.

CRedit Statement

Hwa-Kyung Shin: Writing - Original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Sung-Kyung Choi:** Writing - Review and editing, Validation, Experiment, Conceptualization.

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