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Research Article

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Accessory Respiratory Muscle Activation during Chest Expansion Exercise using Elastic Bands in Children with Cerebral Palsy

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| Abstract |

PURPOSE: The aim of this study was to evaluate activation of accessory respiratory muscles using electromyography during chest expansion upper extremity flexion, abduction, and external rotation exercises with an elastic band in children with cerebral palsy.
METHODS: The subjects were 10 children with cerebral palsy. The inclusion criterion for participation was a Gross Motor Function Classification System level of I to III. The subjects were instructed to perform upper extremity flexion, abduction, and external rotation exercises with inspiration, and extension, adduction, and internal rotation exercises with expiration while seated on a chair without a backrest. PM (Pectoralis major), SCM (sternocleidomastoid), RA (rectus abdominis), and EO (external oblique) muscle activities were measured using electromyography.
RESULTS: All tested muscles showed a statistically significant increase in activity after elastic band exercise. There were significant differences in PM, SCM, RA, and EO results after chest expansion exercise using elastic band. SCM showed the largest increase in activity after use of elastic bands, at 52.37±45.88%, followed by the RA (50.56±79.31), EO (35.42±35.45), and PM (31.72±25.64). The increase in the SCM was greatest, followed by increases in the RA, EO, and PM
CONCLUSION: These finding suggest that activity of accessory respiratory muscles increases with use of elastic bands during chest expansion exercise in cerebral palsy.

Key Words: Accessory Respiratory muscle, Cerebral palsy, Chest expansion, Elastic band

Ⅰ. Introduction

Cerebral palsy is a major disease in children, and causes posture and activity disorders. It is associated with brain injury in utero or during birth (Bax et al., 2005). Cerebral palsy in children involved musculoskeletal deformities, shortening and dystrophic changes in muscles, weakness of the entire body, respiratory muscle weakness, asymmetric thoracic growth, and impaired respiratory function, resulting in increased respiratory infections and mortality (Toder, 2000).

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Respiratory muscle weakness causes breathing difficulty when performing activity. Therefore, intervention is needed to strengthen respiratory muscles, reduce dyspnea, and enhance exercise tolerance (Mulreany et al., 2003). Physical therapy used to strengthen the respiratory muscles and enhance pulmonary function includes chest expansion resistance training, abdominal breathing, and pursed-lip breathing (Kisner and Collby, 2012). Individuals who experience difficulty breathing tend to compensate by excessive use of accessory respiratory muscles, including the PM and SCM during inspiration, and RA, EO, and internal oblique (IO) during expiration (Moreno et al., 2005; Kendall et al., 2005; Ratnovsky et al., 2008).

With upper extremity flexion, abduction, and external rotation against resistance, the major respiratory muscles (the diaphragm and intercostal muscles) are activated (Moreno et al., 2005) together with the accessory respiratory muscles the PM and serratus anterior (Sullivan and Portney, 1980), which helps expand the chest and improve breathing (Areas et al., 2013).

Since resistance training enhances muscle strength and endurance, improves oxygen carrying capacity, modifies muscle type, and decreases muscle fatigue in orthopedic patients, it is also often used in patients with cardiovascular disease (Bennell and Hinman, 2011; Braith and Beck, 2008). Children with cerebral palsy receive direct manual resistance therapy and training with a barbell or other equipment. However, the degree of resistance applied by therapists is variable, and difficulty with objective measurement can arise when using such methods. Resistance training using elastic bands has recently been widely used to compensate for these limitations (Ham, 2000; Choi et al., 2010; Lin and Sung, 2012; Areas et al., 2013). Elastic bands are convenient, economical, and safe to use, and provide resistance without relying on gravity; elastic bands do not impose spatial limitations, and are commonly used in clinical practice (Simoneau et al., 2001).

Electromyography (EMG) during chest expansion with accessory respiratory muscles is commonly used in patients with respiratory diseases (Ng and Stokes, 1992; Maarsingh et al., 2000).

This study therefore aims to evaluate upper extremity flexion, abduction, and external rotation against resistance in children with cerebral palsy, and to investigate changes in activation of accessory respiratory muscles during chest expansion.

Ⅱ. Methods

1. Subjects

This study was conducted in 10 children with cerebral palsy who agreed to participate in the research (boys: 5, girls: 5)

The inclusion criterion for participation was a Gross Motor Function Classification System level of I to III. The average age, height, and weight of participants was 8.10±3.25 years old, 114.18±13.37 cm, and 23.14±8.47 kg.

2. Procedure

All subjects performed chest expansion exercises with upper extremity flexion, abduction, and external rotation while knee does not widen on seated on a chair without an armrest and backrest. The subjects were instructed to: 1) breathe in and out at rest; then, 2) perform upper extremity flexion, abduction, and external rotation with inspiration, and extension, adduction, and internal rotation with expiration without a yellow Thera-Band (Hygenic Corporation, Akron, OH, USA). and then, 3) perform the same exercises with a yellow Thera-Band.

For data collection, subjects performed three trials of each exercise with a 1-min rest period between trials. The EMG signals collected during the three exercises were expressed as a percentage of the calculated root mean square of a reference voluntary contraction (%RVC).

3. Data collection and EMG processing

Surface EMG (LXM5308, LAXTHA Inc., Korea) was used to record activity of the PM, SCM, RA, and EO muscles. Disposable bipolar Ag/AgCl surface electrodes were positioned at an inter-electrode distance of 2 cm. Prior to applying the electrodes, skin impedance was reduced by cleansing with an alcohol swab. Electrode placements for each muscle were as follows: PM - (sternal fibers) located on the chest wall parallel to the muscle origin (approximately 2 cm lateral to the axillary fold); SCM - placed at lower 1/3 of the line connecting sternal notch and mastoid process; RA - 3 cm superior to the umbilicus and 2 cm lateral to the midline; EO - an oblique arrangement above the anterior superior iliac spine and lateral to the umbilicus (Cram et al., 1998; Falla et al., 2002).

The EMG signals were band-pass filtered from 20 to 500 Hz and sampled at 1024 Hz. Following data collection, EMG signals were rectified and smoothed using the root mean square (RMS) for raw data. RVCs were collected to normalize the EMG data of the PM, SCM, RA, and EO.

4. Data analysis

Collected data were analyzed using SPSS version 22.0 (SPSS, Inc., Chicago, IL, USA). All data showed non-normal distributions according to the Kolmogorov-Smirnov test. Wilcoxon signed-rank tests were used to compare differences in muscle activity between two conditions (Non-band vs. Band exercise)

Ⅲ. Results

1. EMG activities

EMG activities of each muscle tested during the chest expansion exercises with upper extremity flexion, abduction, and external rotation are summarized in Table 1.

There were significant differences in PM, SCM, RA, and EO results after chest expansion exercise using elastic band. SCM showed the largest increase in activity after use of elastic bands, at 52.37±45.88%, followed by the RA (50.56±79.31), EO (35.42±35.45), and PM (31.72±25.64).

Ⅳ. Discussion

Children with cerebral palsy have impaired breathing. The diaphragm contracts excessively during inspiration to compensate for weakened respiratory muscles, the lower rib cage flares outward, and the sternum is retracted because it cannot overcome the strong pulling force. This causes the mid-thorax to retract, giving the chest a funnel-like appearance (Crystal, 1997). Due to impaired breathing, patients tend to compensate by excessive use of the accessory respiratory muscles, including the PM and SCM during inspiration, and RA, EO, and IO during expiration (Moreno et al., 2005; Kendall et al., 2005; Ratnovsky et al., 2008). With upper extremity flexion, abduction, and

Table 1. Electromyography activities (%RVC) during chest expansion with upper extremity flexion, abduction, and external rotation

(unit: %RVC)

	Non-band	Band	P value
PM	50.89±47.76	104.94±82.42	.01**
SCM	167.12±130.53	295.45±179.23	.01**
RA	13.16±18.75	65.47±75.25	.01**
EO	16.35±13.02	65.51±49.11	.02*

Mean±SD,
PM: pectoralis major, SCM: sternocleidomastoid, RA: rectus abdominis, EO: external oblique

external rotation against resistance, the major breathing muscles (diaphragm and intercostal muscles) are activated (Moreno et al., 2005) together with the accessory respiratory muscles (PM and serratus anterior) which expands the chest and improves breathing (Areas et al., 2013; Sullivan and Portney, 1980). In addition Sullivan and Portney (1980) studied the electromyographic activity of various upper limb PNF patterns (upper extremity flexion, abduction, and external rotation) and described that the same movement used in this study activates the muscles of the pectoralis major and serratus anterior, both accessory respiratory muscles, and may possibly have an effect on the increase in respiratory muscle activity. However, there has been a lack of research on muscle activation in the accessory respiratory muscles in children with cerebral palsy.

Therefore, this study implemented a chest expansion exercise in children with cerebral palsy, in order to investigate whether resistance training using elastic bands affects muscle activation in accessory respiratory muscles.

The study showed that muscle activity of SCM was greatest when elastic bands were not used in chest expansion exercise, and this was statistically significant. This result indicates that during the study, the SCM was used as an accessory muscle more than the PM, with upper extremity flexion, abduction, and external rotation during inspiration. As Czaplinski et al. (2006) reported, the SCM acts as an upper torso and accessory inspiratory muscle that raises the thorax during inspiration, expands lung volume, and therefore affects forced vital capacity. Areas et al. (2013) reported a positive effect on respiratory muscle strength with upper extremity flexion, abduction, and external rotation exercise using elastic bands.

Trunk stability is essential for raising and lowering the upper limb while sitting. (Hodges and Richardson, 1997a; Hodges and Richardson, 1997b). Lee et al. (2016) investigated whether elastic band use during upper extremity lifting can activate the ipsilateral external oblique muscle. Jeon (2013) stated that trunk muscle strengthening exercise and use of a trunk belt leads to improved trunk control ability and pulmonary function. Considering that strength is a condition for upper and lower limb movement once trunk stability is achieved, this result shows that the patient recruits as much RA muscle strength as possible to overcome resistance from the elastic band and raise the upper limbs. Choi et al. (2013) also reported that RA muscle strength can alter upper extremity function. Thus, upper limb chest expansion exercises using elastic bands greatly different activation of accessory respiratory muscles in children with cerebral palsy.

This study was limited by the small sample of children with cerebral palsy. Additional studies are needed to investigate the effects on pulmonary function in children with cerebral palsy by measuring respiratory muscle and pulmonary function, in addition to changes in muscle activity.

Ⅴ. Conclusion

In clinical practice, upper extremity flexion, abduction, and external rotation, even without elastic bands, may assist respiration in children with cerebral palsy who have respiratory muscle weakness, by activating accessory respiratory muscles. As the study shows, upper extremity exercise for chest expansion increases PM, SCM, RA, and EO accessory respiratory muscle activities during inspiration and expiration. This suggests that chest expansion exercise using elastic bands can have a positive effect on accessory respiratory muscle activity.

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