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Original Article

Upper extremity resistance exercise with elastic bands for respiratory function in children with cerebral palsy

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Abstract. [Purpose] We investigated the effects of upper extremity resistance exercise with elastic bands on respiratory function in children with cerebral palsy. [Subjects and Methods] Fifteen children were divided into two groups: the experimental (n=8) and control (n=7) groups. Both groups performed general exercises for 30 minutes per session, two times a week during the intervention period. The experimental group performed an additional upper extremity resistance exercise with elastic bands for 20–30 minutes per session, twice weekly for 8 weeks. Pulmonary function, and respiratory muscle and grip strength were measured before and after the exercise. [Results] There was no significant difference in forced vital capacity, forced expiratory volume in one second, the ratio of forced expiratory volume in one second to forced vital capacity, and peak expiratory flow before and after the intervention in either group. The increment of maximal expiratory pressure was significantly greater in the experimental group, compared with the control group. In addition, grip strength was significantly increased in the experimental group after the intervention than before. [Conclusion] We found that upper extremity resistance exercise with elastic bands has a positive effect on expiration and improves grip strength in children with cerebral palsy.

Key words: Cerebral palsy, Upper extremity resistance exercise, Respiratory function

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INTRODUCTION

Cerebral palsy is characterized by impaired motor function and posture in children due to prenatal or postnatal brain damage[1)]. Children with cerebral palsy not only have musculoskeletal deformities, including joint contracture, shortened muscle, and muscle dystrophy, but also compromised respiratory function such as reduced pulmonary volume due to weakness in respiratory muscles and asymmetric chest growth, which can increase the rate of respiratory system infection and mortality[2, 3)]. Furthermore, respiratory muscles in the chest and abdomen do not activate properly during respiration. As a result, they show abnormal respiratory patterns where the inspiratory and expiratory muscles contract together during inspiration, instead of the expiratory muscles relaxing when inspiratory muscles contract[4)]. During inspiration, the diaphragm contracts excessively to compensate for weakened respiratory muscles, which causes the chest to show a concave funnel shape from the lower ribs expanding outward and the sternum collapsing, because they cannot withstand the strong pulling force[5)]. Moreover, inability to discharge foreign substances and secretions from the airway and ventilation difficulties due to weakened respiratory muscles may cause pneumonia as well as other respiratory complications[2)].

Abnormal respiratory patterns and restricted chest movement in these children cause irregular and rough respiration, which affects the respiratory muscles and pulmonary function, leading to a gradual deterioration of their respiratory function if proper prevention and treatment measures are not taken[5)]. Therapeutic interventions addressing weakened respiratory

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muscle strength can build-up exercise tolerance and reduce shortness of breath[6)].

In particular, respiratory muscle strengthening interventions in this patient population predominantly target the respiratory muscles, such as trunk belts directly being applied to respiratory muscles[7)], feedback respiratory exercise using respiratory muscle training equipment[8)], and applying functional electro-stimulation on the rectus abdominis muscle[9)]. However, to improve pulmonary function in these children with restricted chest movement, it is necessary to not only increase respiratory muscle strength, but also chest mobility.

Applying resistance during upper extremity flexion, abduction, and external rotation activates major respiratory muscles, the diaphragm, and intercostal muscles[10)], as well as respiratory accessory muscles, the pectoralis major, and serratus anterior[11, 12)], expanding the chest to affect respiratory function[13)]. To our knowledge, interventions using elastic bands have been predominantly used to improve range-of-motion, balance, and strength, and data are lacking on the effects of resistance with elastic bands on the respiratory function of children with cerebral palsy[14)]. Studies evaluating the impact of upper extremity resistance exercise on the respiratory function of this patient population are also lacking.

The objective of our study was to examine the effects of upper extremity resistance exercise using elastic bands on the respiratory function of children with cerebral palsy.

SUBJECTS AND METHODS

We evaluated children with cerebral palsy undergoing exercise therapy at a rehabilitation social welfare center at "U" City in Korea. Children were eligible for study inclusion if they had cerebral palsy with: 1) Gross Motor Function Classification System (GMFCS) grade I–III; 2) Manual Ability Classification System (MACS) grade I–III; 3) did not receive any other respiratory treatment; and 4) were capable of fully understanding and following the instructions provided by the researcher to measure respiratory function. Overall, 15 children met the inclusion criteria and were included in the study. Eight children were randomized to the experimental group and 7, the control group. The mean age, height, and weight was 9.25 ± 3.65 years, 122.01 ± 20.37 cm, and 29.60 ± 14.79 kg in the experimental group and 9.57 ± 4.54 years, 125.86 ± 23.93 cm, and 32.71 ± 20.88 kg in the control group, respectively. No significant differences were found between the groups. Informed consent was sought from the patients and guardians to participate in the study. All protocols were approved by the Ethics Committee of the Catholic University of Pusan (CUPIRB-2015–025).

A professionally trained therapist provided 8 weeks of neurodevelopmental treatment to children in both groups, each session lasted 30 min. Children in the experimental group received an additional 8 weeks of upper extremity resistance exercise with elastic bands, 20–30 min per session, and 2 sessions weekly, concurrent with the neurodevelopment treatment. The upper extremity exercise included an elastic band (Thera-Band®, Hygenic Corporation, Akron, OH, USA) and involved sitting in a chair without arm rests or a back rest, with the knees of the child strapped together to prevent them from coming apart. The patient grasp the elastic band fully expanding the chest by moving the upper extremity in flexion, abduction, and external rotation direction without elbow flexion.

In weeks 1 and 2, the elastic band was set to stretch by 80% and 2 sets of 10 repetitions per set were performed. In weeks 3 and 4, the elastic band was set to stretch 100% and 2 sets were performed. In weeks 5 and 6, 3 sets were performed, while in weeks 7 and 8, 4 sets were performed. A 1-minute rest period was provided between each set and the exercise was discontinued immediately if the participant experienced any breathing difficulties or discomfort during the exercise. The exercise was performed with the same intensity for 10 repetitions using the band appropriate for the number of repetitive motions based on the recommendations of the manufacturer. The therapist supervised the exercise and ensured that the participants maintained proper posture and the direction of exercise was accurate, as well as provided feedback regarding the accuracy of the exercise.

A spirometer (Pony Fx, CosmedSrl, Italy) was used to measure forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow (PEF), maximal inspiratory pressure (MIP), and maximal expiratory pressure (MEP) and a hand grip dynamometer (T.T.K.5401,Takei, Japan) was used to measure grip strength before and after the intervention to each group. Collected data were analyzed using SPSS version 22.0 (SPSS, Inc., Chicago, IL, USA). After the normality test, the results were analyzed using non-parametric statistics. Differences within each group before and after the experiment were analyzed using Wilcoxon Signed-Rank test, and differences in means between two groups were analyzed using Mann-Whitney U test. All statistical significance levels were set to $p<0.05$.

RESULTS

Comparisons of pulmonary function, respiratory muscle strength, and grip strength between experimental and control groups are summarized in Table 1. Compared with baseline, MEP increments were significantly greater the intervention in the experimental group, compared with in the control group. Grip strength was also significantly greater in the experimental group after the intervention than before hand.

Table 1. Comparisons of pulmonary function, respiratory muscle strength, and grip strength between experimental and control groups

Variable			Pre	Post	Z	Post-Pre	Z
Pulmonary function	FVC (L)	Experimental	1.37 ± 0.75	1.45 ± 0.69	−1.051	0.09 ± 0.22	−1.27
		Control	1.62 ± 1.19	1.52 ± 0.96	−0.338	−0.09 ± 0.26	
	FEV1 (L)	Experimental	1.13 ± 0.61	1.30 ± 0.55	−1.682	0.17 ± 0.23	−1.04
		Control	1.38 ± 0.98	1.44 ± 0.89	−1.214	0.06 ± 0.16	
	FEV1/FVC (%)	Experimental	83.50 ± 12.65	90.38 ± 7.31	−1.521	6.88 ± 13.49	−0.87
		Control	86.86 ± 7.54	94.14 ± 3.48	−1.992	7.29 ± 6.47	
	PEF (L/min)	Experimental	1.98 ± 1.03	2.44 ± 1.09	−1.400	0.46 ± 0.83	−0.34
		Control	2.49 ± 2.05	2.77 ± 2.44	−1.101	0.28 ± 0.64	
Respiratory muscle strength	MIP (cmH2O)	Experimental	37.75 ± 22.40	39.62 ± 15.48	−0.140	1.88 ± 22.29	−0.23
		Control	38.29 ± 18.22	41.43 ± 27.78	−0.526	3.14 ± 11.88	
	MEP (cmH2O)	Experimental	43.50 ± 12.06	49.50 ± 16.35	−1.266	6.00 ± 10.42	−2.20*
		Control	42.29 ± 15.61	33.83 ± 12.78	−1.753	−8.29 ± 9.66	
Grip strength (kg)		Experimental	8.82 ± 4.15	9.64 ± 3.53	−2.035*	0.82 ± 0.98	−1.913
		Control	12.73 ± 12.28	12.50 ± 12.72	−0.420	−0.23 ± 1.28	

FVC: forced vital capacity; FEV1: forced expiratory volume in one second; PEF: peak expiratory flow; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure.
*$p<0.05$.

DISCUSSION

In this study, we investigated the effects of upper extremity resistance exercise on respiratory function in children with cerebral palsy using elastic bands. We found that FVC, FEV1, and PEF increased by 6%, 15%, and 23% in the experimental group, respectively, although the trends were not statistically significant. The increase in FVC we observed may have been attributed to increased muscle activity in the sternocleidomastoid muscle, a respiratory accessory muscle, during resistance exercise with the elastic bands[15)]. This in turn may have increased FVC, increasing pulmonary volume by lifting the chest upward during inspiration[16)]. After the intervention, MIP and MEP increased by 5% and 14% in the experimental group, respectively, whereas MIP and MEP decreased by 8% and 20% in the control group. However, these changes were not statistically significant. We believe this was the case because the children included in our study had diminished muscle coordination from musculoskeletal deformities, chest asymmetry, and weakened respiratory muscles.

However, the experimental group that received the intervention showed an increase in MEP, whereas the control group showed a decrease in MEP; no significant change was seen between the groups. We believe that the reason why MEP increased in the experimental group was due to the activation of the rectus abdominis muscle as resistance exercise was performed with the upper extremity while being lifted up. Stability in the trunk must be achieved to perform the intervention, which involved flexion, abduction, and external rotation of the upper extremity[17, 18)]. To maintain trunk stability, the diaphragm, intercostal, oblique abdominis, and rectus abdominis muscles must contract simultaneously, because these muscles are responsible for expiration and inspiration[19)]. MEP decreased in the control group, which suggested that even without direct intervention on the respiratory muscles, lack of interest in improving respiratory function can have a future negative effect on the respiratory function and not performing respiration-related exercise can cause rapid decrease in respiratory muscle strength[20)]. Therefore, we believe that continued respiratory physical therapy intervention is needed for the prevention and improvement of respiratory issues in children with cerebral palsy. Moreover, increased expiratory muscle strength during respiration can improve the act of coughing, which can help discharge foreign substances and secretions from the airway, and to prevent pneumonia and other respiratory complications[21)].

In a study that investigated the correlation between grip strength and respiratory muscles in the elderly, muscle strength was found to be positively correlated with MIP and MEP ($r=0.35$, $r=0.26$), while the regression analysis results showed that grip strength was one of the factors for MIP and peak cough flow (PCF)[22)]. The experimental group showed a significant increase of 9% in grip strength from pre- to post-intervention. Respiratory muscle strength is associated with extremity muscles, and in particular, grip strength can represent the overall physical strength[23)]. Grip strength is affected by the stability in the shoulder girdle near the shoulder joint. Stability in the shoulder girdle is involved in chest movement during respiration and controls the intra-abdominal pressure used by respiratory accessory muscles[24)]. A study that examined 17 children with cerebral palsy also reported that grip strength was highly correlated with pulmonary function and respiratory muscle strength[21)]. These data indicate that increased grip strength in children with cerebral palsy activate respiratory accessory muscles to have a positive effect on improving respiratory function.

Altogether, our results demonstrate that applying upper extremity resistance exercise with elastic band activates respiratory accessory muscles, increases grip strength, and has a positive impact on the respiratory function of children with cerebral palsy. However, since the sample size was small and there were limitations in participant selection based on types of cerebral palsy, continued studies and intervention with these issues resolved are needed for improving the respiratory function of children with cerebral palsy.

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