Original Article

Comparison of differences in respiratory function and pressure as a predominant abnormal movement of children with cerebral palsy

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Abstract. [Purpose] The purpose of this study was to determine differences in respiratory function and pressure among three groups of children with cerebral palsy as a predominant abnormal movement which included spastic type, dyskinetic type, and ataxic type. [Subjects and Methods] Forty-three children with cerebral palsy of 5–13 years of age in I–III levels according to the Gross Motor Function Classification System, the study subjects were divided by stratified random sampling into three groups of spastic type, dyskinetic type, and ataxic type. For reliability of the measurement results, respiratory function and pressure of the children with cerebral palsy were measured by the same inspector using Spirometer Pony FX (Cosmed Ltd., Italy) equipment, and the subject's guardians (legal representative) was always made to observe. [Results] In the respiratory function, there were significant differences among three groups in all of forced vital capacity, forced expiratory volume at one second, and peak expiratory flow. For respiratory pressure, the maximal inspiratory pressure had significant differences among three groups, although the maximal expiratory pressure had no significant difference. [Conclusion] Therefore, pediatric physical therapists could be provided with important clinical information in understanding the differences in respiratory function and pressure for the children with cerebral palsy showing predominantly abnormal movement as a diverse qualitative characteristics of the muscle tone and movement patterns, and in planning intervention programs for improvement of respiratory capacity.

Key words: Cerebral palsy, Respiratory function, Respiratory pressure

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INTRODUCTION

Cerebral palsy is a clinical syndrome where permanent disorders in development of posture and movement are caused by non-progressive disturbances occurring in the brain of fetus or infant producing activity limitation, and is frequently accompanied by disorders in sensation, cognition, communication, perception, and conduct as well as seizure, etc¹⁾. Since the cerebral palsy has diversified characteristics in muscle tone and form of movement disorder due to brain damages²⁾, it can be classified into spastic type (60–70%), dyskinetic or athetoid type (20–30%), ataxic type depending on the predominant abnormal movement³⁾. Thus, movement disorders as a function of diversified types of children with cerebral palsy induce secondary complications and functional activity limitations related to skeletal muscles system, and also affect respiratory function^{4, 5)}.

Whereas normal respiration requires normal functions of nervous system, respiratory muscles, and costovertebral joint, the children with cerebral palsy have weak muscular strength of the whole body including respiratory muscles, and fail to

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properly remove airway secretions due to spasm so that abnormal respiratory functions such as pneumonia, atelectasis, epipharyngitis, etc. occur^{6, 7)}. Also, pulmonary functions are reduced as abnormal respiration methods such as shallow breathing, reverse breathing pattern of children with cerebral palsy over a long period shorten respiratory muscles, and induce stiffness in costovertebral joint to limit thoracic cage mobility⁸⁾. Therefore, although the children with cerebral palsy do not have practical problems with lung, weakening of respiratory muscles due to neurological damages causes reduction in thoracic cage compliance, ventilator failure, degradation in airway clearance capacity leading to a decrease in lung volume, resulting in long-term hospitalization or mortality increase due to respiratory diseases^{7, 9, 10)}. According to the recent studies, the children with cerebral palsy are exposed to not only pulmonary function disorders but practically risks of pulmonary diseases^{6, 11)}, and many previous studies stated that the correlation between motor function disorders and respiratory functions was high^{12–14)}.

Since respiratory muscles are essential to functional body movement and contribute to air inflow and discharge of the lung, ventilation function is reduced so as to obstruct lung's gas exchange when such pump action is weakened¹⁵⁾. Therefore, to improve respiratory functions important for heart and lung capacities, training for respiratory muscles is also as important as in other skeletal muscles. Respiratory training improves not only the muscle strength and endurance but also the sense of wellbeing in daily living¹⁶⁾, and may affect changes in maximal inspiratory pressure and maximal expiratory pressure^{17, 18)}. Therefore, functions of respiratory muscles can be evaluated through mechanical measurement of maximal inspiratory pressure and expiratory pressure in the state of biting a mouthpiece with lips to prevent escape of air held inside the mouth. According to the previous studies, measurement of maximal inspiratory pressure and expiratory pressure was said to have more value in evaluating the function of respiratory muscles while measurement of pulmonary function is very important for clinical usefulness^{19, 20)}.

Therefore, the purpose of this study was to determine differences in respiratory function and pressure among three groups of children with cerebral palsy as a predominant abnormal movement which included spastic type, dyskinetic type, and ataxic type. It was also conducted to provide clinically more useful basic data concerning where to put the emphasis in conducting respiratory training as a predominant abnormal movement in order to prevent worsening of pulmonary function of the children with cerebral palsy.

SUBJECTS AND METHODS

The present study was conducted to compare differences in respiratory function and pressure among three groups of spastic type, dyskinetic type, and ataxic type, and was approved in advance by the Bioethics Committee of Dong-Eui University (IRB No. DIRB-201510-HR-R-029). Forty-three children with cerebral palsy as the study subjects were divided by stratified random sampling into three groups of spastic type, dyskinetic type, and ataxic type. The detailed selection criteria for the subjects were first, the children of 5–13 years of age having been diagnosed as cerebral palsy by specialized doctors in the department of rehabilitation medicine/neurology (neurosurgery); secondly, the children in I–III levels according to the Gross Motor Function Classification System; thirdly, the children capable of task perform per directions given by the investigator and of appropriate communication. First of all, "Subject consent" for voluntary participation was received after a sufficient explanation was given to the study subjects and the guardians (legal representative) concerning study objectives and methods, risks or inconveniences.

For reliability of the measurement results, respiratory function and pressure of the children with cerebral palsy were measured by the same inspector using Spirometer Pony FX (Cosmed Ltd., Italy) equipment, and the subject's custodian (legal agent) was always made to observe. After checking first that health state of the children with cerebral palsy was satisfactory, the inspector conducted repeated education to ensure that measurement methods were sufficiently recognized allowing accurate performance. The cerebral palsy child stared at the front sitting on a chair having back rest in the most convenient clothes for activity, and participated in the measurement of respiratory function and pressure.

For respiratory function, the best measurement result was selected after repetition of more than 3 times so as to have no coughing, no air leaks, no false start, etc. according to the guideline by American Thoracic Society (ATS) (1991). After having the subject breathe air in and out most deeply and rapidly following normal respiration for 3–4 times as in daily living, forced vital capacity (FVC), forced expiratory volume at one second (FEV1), and peak expiratory flow (PEF) were measured. Respiratory pressure was measured after sufficient rest was taken following the test on respiratory function. With a mouthpiece bitten so as to prevent escape of air by maximum adherence to the lips, maximum expiration and inspiration was enforced after usual respiration. For the maximal inspiratory pressure, the subject was made to continue inspiration most deeply and rapidly for more than 2 seconds until the signal sound is heard at the same time as attaching the nose plugs upon maximum expiration so as to be close to residual volume. For the maximal expiratory pressure, the subject was made to continue expiration most deeply and rapidly for more than 2 seconds until the signal sound is heard at the same time as attaching the nose plugs upon maximum inspiration so as to be close to the total lung capacity.

The data collected in the present study was analyzed by using SPSS 22.0 (IBM Corp., USA) for windows program, with the significant level α for statistical verification set to be 0.05. As the general characteristics for the study subjects, frequency

Table 1. General characteristics and medical history of the subjects (Mean $\pm$ SD)

Variances	Mean $\pm$ SD		
	Spastic (n=28)	Dyskinetic (n=9)	Ataxic (n=6)
General characteristics			
Gender (boys/girls)	13/15	5/4	4/2
Age (years)	7.61 $\pm$ 2.78	7.44 $\pm$ 2.88	8.33 $\pm$ 1.86
Height (cm)	114.6 $\pm$ 15.8	120.9 $\pm$ 16.0	120.5 $\pm$ 11.9
Weight (kg)	22.7 $\pm$ 8.2	24.2 $\pm$ 7.1	23.2 $\pm$ 6.3
Medical history			
Delivery (NSVD/C-sec/Induced delivery)	16/9/2	2/4/3	4/3/2
Pregnancy week (weeks)	34.0 $\pm$ 3.9	37.8 $\pm$ 3.6	32.0 $\pm$ 2.8
Birth weight (g)	2,352.1 $\pm$ 564.6	2,991.1 $\pm$ 626.7	2,045.7 $\pm$ 490.5
Incubator care (weeks)	7.9 $\pm$ 13.9	1.7 $\pm$ 2.7	7.3 $\pm$ 5.6

NSVD: normal spontaneous vaginal delivery, C-sec: cesarean section

Table 2. The comparison of respiratory function and pressure in the different groups

Variances	Mean $\pm$ SD		
	Spastic (n=28)	Dyskinetic (n=9)	Ataxic (n=6)
Respiratory function			
FVC (l)*	1.63 $\pm$ 0.10 ^{a, b}	1.40 $\pm$ 0.12 ^{a, c}	1.06 $\pm$ 0.12 ^{b, c}
FEV1 (l)*	1.56 $\pm$ 0.08 ^{a, b}	1.28 $\pm$ 0.14 ^{a, c}	1.06 $\pm$ 0.19 ^{b, c}
PEF (l/sec)*	2.79 $\pm$ 0.27	2.39 $\pm$ 0.48 ^c	2.01 $\pm$ 0.33 ^c
Respiratory pressure			
MIP (cmH ₂ O)*	30.55 $\pm$ 5.52 ^{a, b}	37.90 $\pm$ 3.45 ^{a, c}	24.39 $\pm$ 3.44 ^{b, c}
MEP (cmH ₂ O)	40.85 $\pm$ 9.52	38.71 $\pm$ 7.42	38.73 $\pm$ 10.40

*p<0.05

FVC: forced vital capacity, FEV1: forced expiratory volume in one second, PEF: peak expiratory flow, MIP: maximal inspiratory pressure, MEP: maximal expiratory pressure

^asignificant difference between spastic type and dyskinetic type, ^bsignificant difference between spastic type and ataxic type, ^csignificant difference between dyskinetic type and ataxic type

and descriptive statistics were calculated, and parametric method was implemented after checking for normality of the measured variables through Kolmogorov-Smirnov analysis. To compare differences in respiratory function and pressure among three groups of spastic type, dyskinetic type, and ataxic type as a predominant abnormal movement forms, one-way ANOVA was conducted, and Bonferroni analysis was used for post-hoc.

RESULTS

General characteristics and medical history of the study subjects are shown in Table 1. No significant differences in the variables of general characteristic and medical history were observed among three groups (p<0.05). The analysis results for comparison of averages of respiratory function and pressure among three groups of spastic type, dyskinetic type, and ataxic type as a predominant abnormal movement of the children with cerebral palsy are presented in Table 2. In the respiratory function, there were significant differences among three groups in all of forced vital capacity, forced expiratory volume at one second, and peak expiratory flow (p<0.01). According to the post-hoc results, the forced vital capacity and the forced expiratory volume at one second showed a significant difference between spastic type and dyskinetic type, between spastic type and ataxic type, and between dyskinetic type and ataxic type, respectively. Although the peak expiratory flow showed no significant differences between spastic type and dyskinetic type, and between spastic type and ataxic type, it showed a significant difference only between dyskinetic type and ataxic type. For respiratory pressure, the maximal inspiratory pressure had significant differences among three groups (p<0.01), although the maximal expiratory pressure had no significant difference. According to the post-hoc results, significant differences were observed between spastic type and dyskinetic type, between spastic type and ataxic type, and between dyskinetic type and ataxic type.

DISCUSSION

Although the brain damage itself is not a direct cause producing respiratory problems of the cerebral palsy⁸⁾, the children with cerebral palsy showed much lower values in not only general respiratory function but also respiratory muscle strength which is very closely related to self-care activities and social adaptiveness in daily living when compared with normal children²¹⁾. In a study of comparing respiratory function and pressure for the children with cerebral palsy according to the gross motor function classification system, the children with cerebral palsy with low motor function were found to exhibit relatively unsatisfactory pulmonary capacity and weakening of respiratory muscles¹¹⁾. Also, even for the children with cerebral palsy of spastic type, it was stated that significant differences existed in trunk expansion, respiratory muscle strength, and pulmonary function depending the invasive part for diplegia and hemiplegia²²⁾, and that muscle strength of respiratory muscles of the children with cerebral palsy should be considered for establishment of intervention plans to improve functions in daily living, since it had positive correlations with self-management in activities of daily living and performance level for social function²³⁾. However, since diversified clinical problems are revealed due to weakening of respiratory muscles and damages to coordination exercise in the case of children with cerebral palsy, there is much difficulty in evaluation of respiratory capacity so that multi-faceted studies are not being realized⁷⁾. Therefore, it is considered clinically as a quite necessary study to find differences in respiratory function and pressure after classification of the children with cerebral palsy showing diversified qualitative movement characteristics in muscle tone and motion pattern according to the predominant abnormal movement into three groups of spastic type, dyskinetic type, and ataxic type.

In the spastic type of cerebral palsy with high muscle tone, immature diaphragm respiration occurs upon expiration due to stiff ribs and lack of spine mobility with rib cage not expanding in front/rear, left/right, up/down directions, as a result of which forced vital capacity and forced expiratory volume at one second were reduced. Also, since the maximal inspiratory pressure is difficult to maintain due to the delay in diaphragm contraction, the children with cerebral palsy of spastic type is considered to have attempted shallow and rapid breathing. As repetition of such irregular respiration periods disables inspiration for a long time, abilities to maintain peak expiratory flow and maximal expiratory pressure are also considered to have been reduced.

The ataxic type showing fluctuation of muscle tone and involuntary movement is incapable of having a fixed posture with a tendency of the control of coordination exercise being difficult upon inspiration and expiration of thoracic and abdomen parts. Namely, since the abdomen muscle is unconsciously activated whereas the thoracic muscle is mainly used for auxiliary purpose in the ataxic type, other muscle groups are active with expiration when one muscle group is engaged in inspiration action. In this way, unsynchronized movements induced in abdominal muscles, diaphragm and thoracic muscles produce shallow, rapid and uncoordinated respiration, while a platy upper rib cage and a small rib cage as a whole with the sternum lowered and the lower rib flared in the shape of morning glory are formed. The ataxic type showed generally higher measured values for respiratory function and pressure than the ataxic type although it had lower average values for forced vital capacity, forced expiratory volume at one second and peak expiratory flow than the spastic type. This suggests that the spastic type has relatively better respiratory function and pressure than the ataxic type since excessive co-contraction of the trunk helps stability although the spastic type has insufficient selective movement due to high muscle tone whereas the ataxic type has instability due to insufficient co-contraction of the trunk making respiration difficult. Also, since the children of ataxic type has rapid and irregular respiration occurring together with vocalization, they are characterized by speaking while inspiring or momentarily producing explosive sounds. The maximal expiratory pressure is considered to have the lowest value as it is difficult to continuously produce sounds although the maximal inspiratory pressure was shown to be the highest among three groups.

The ataxic type has a lower capacity to maintain the posture against gravity since the muscle tone as a whole is in the lower state than the normal. Also, since very shallow inspiration is observed due to the lack of co-contraction of trunk muscle, it is considered that general respiration function and pressure were shown to be the lowest compared with the spastic type and the dyskinetic type. In the present study, the ataxic type was observed to have a higher maximal expiratory pressure than the dyskinetic type, which is considered attributable to the long stretched pronunciation when the child of ataxic type speaks.

In the present study, respiratory function of the children with cerebral palsy was observed to show significant differences among three groups in all of forced vital capacity, forced expiratory volume at one second, and peak expiratory flow, with the ataxic type showing the lower values than the spastic type as well as the dyskinetic type. Also, although all measured values of maximal expiratory pressure and respiratory pressure were similar for three groups, the ataxic type showed the lowest maximal inspiratory pressure compared with the dyskinetic type and the spastic type as in the respiratory function. Therefore, pediatric physical therapists could be provided with important clinical information in understanding the differences in respiratory function and pressure for the children with cerebral palsy showing predominantly abnormal movement as a diverse qualitative characteristics of the muscle tone and movement patterns, and in planning intervention programs for improvement of respiratory capacity.

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