Differences of the Truncal Expansion and Respiratory Function between Children with Spastic Diplegic and Hemiplegic Cerebral Palsy

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Abstract. [Purpose] We attempted to determine whether differences of respiratory function could be found in terms of truncal expansion, respiratory muscle strength, and pulmonary function test (PFT) between children with spastic diplegic and hemiplegic cerebral palsy. [Subjects and Methods] We recruited 19 children with spastic diplegic CP (diplegic-CP group) and 10 children with spastic hemiplegic CP (hemiplegic-CP group). For all the children, clinical factors associated with respiratory functions were assessed in terms of truncal expansion (chest and waist expansion), respiratory muscle strength (maximal inspiration and expiration pressures: MIP and MEP), and pulmonary function test (FVC, FEV1, and FEV1/FVC). [Results] Overall, the diplegic-CP group showed lower truncal circumference, respiratory muscle strength, and pulmonary function values than the hemiplegic-CP group. However, in the comparison of the two groups significant differences were only found in waist expansion, MIP, MEP, FVC, and FEV1. [Conclusion] The results of this study indicate that children with diplegic CP have much poorer waist expansion, weaker respiratory muscle, and lower pulmonary function values. These findings will provide valuable information for use in the clinical assessment and treatment of children with spastic CP.

Key words: Spastic cerebral palsy, Respiratory muscle strength, Pulmonary function test

INTRODUCTION

Cerebral palsy (CP) commonly involves pulmonary dysfunction due to motor disability of the respiratory muscles caused by brain injury, which results in a high incidence of mortality or long-term hospitalization1, 2). Children with CP who have respiratory problems show a poorly coordinated pattern of respiratory muscles, shallow and low breathing volume, and decreased cardiopulmonary capacity. These symptoms often cause parenchymal lung pathology (widespread micro-atelectasis and reduced lung distensibility), which impairs of motor development and performance of functional activities in their lives3, 4).

According to many prior studies5-8), pulmonary patients with restrictive lung disease show poor expansion of the chest and waist circumferences, respiratory muscle weakness, and low values in pneumotachograph test. Comparative studies of differences in respiratory function between children with CP and those with normal development have already been published9, 10). However, to the best of our knowledge, few comparative studies of the differences in various respiratory functions (e.g., the chest and waist expansion, respiratory muscle strength, and PFT) between children with spastic diplegic CP and those with hemiplegic CP have been published. Therefore, we investigated whether the respiratory functions of children with spastic diplegic CP differ from those of children with spastic hemiplegic CP, in terms of truncal expansion, respiratory muscle strength, and the pulmonary function test (PFT).

SUBJECTS AND METHODS

Twenty-nine children who suffered from spastic diplegic and hemiplegic cerebral palsy were recruited for this study. The subjects were included according to the following criteria: 1. children with spastic diplegic and hemiplegic cerebral palsy diagnosed by a pediatric medical doctor from brain MRI, 2. no language or cognitive problem that could have affected respiratory strength and pulmonary function measurements, 3. no psychiatric or neurological symptoms except cerebral palsy, 4. levels I, II, and III of the Gross Motor Function Classification System (GMFCS). The subjects consisted of 19 children with spastic diplegic cerebral palsy (diplegic-CP group: 7 boys, age 11.16±1.46), and 10 children with spastic hemiplegic cerebral palsy (hemiplegic-CP group: 7 boys, age 10.10±1.29), who were matched according to gender, age, height, weight, and body surface area. For the distribution of the GMFCS level, the diplegic-CP group had 4 children at level I, 2 children at level II, and 13...
children at level III, whereas the hemiplegic-CP group had 9 and 1 children at levels I and II, respectively. All parents of the children with CP gave their written informed consent for their children’s participation in this study. The experimental protocol was approved by the local ethics committee.

Truncal expansion was assessed as circumference differences of the chest and waist between inspiration and expiration with maximal voluntary effort. All children were instructed to inhale or exhale as deeply as possible, and then to hold their breath for several seconds. At that time, the chest and waist circumferences were measured by a pediatric physical therapist using a tape marked in 0.1 cm increments, as described in prior studies[7, 11]. Chest circumference was measured horizontally at the level of the fourth intercostal region, the articulated junction between the xiphoid process and sternum. Waist circumference was measured horizontally around the narrowest part of the trunk, between the lowest rib and the iliac crest.

The maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were used as measures of respiratory muscle strength. These tests assess the highest pressure that respiratory muscles are able to generate against an occlusion at the mouth, which was measured with a Micro Respiratory Pressure Meter (Micro Direct Inc., USA). The children were seated and instructed to breathe in or out against the occluded mouthpiece with maximal voluntary effort with as much force as possible, while keeping the lips sealed tightly around the mouthpiece. The MIP and MEP are used as measures of respiratory muscle strength, as a routine procedure in pulmonary function measurement[12].

The pulmonary function test (PFT) was assessed by the same examiner using a spirometer (Vmax 229, SensorMedics, USA) throughout the entire experiment. All the children were instructed to inhale or exhale as deeply as possible, and then to hold their breath for several seconds. At that time, the chest and waist circumferences were measured by a pediatric physical therapist using a tape marked in 0.1 cm increments, as described in prior studies[7, 11]. Chest circumference was measured horizontally at the level of the fourth intercostal region, the articulated junction between the xiphoid process and sternum. Waist circumference was measured horizontally around the narrowest part of the trunk, between the lowest rib and the iliac crest.

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The pulmonary function test (PFT) was assessed by the same examiner using a spirometer (Vmax 229, SensorMedics, USA) throughout the entire experiment. All the children were instructed to inhale or exhale as deeply as possible, and then to blow out through a mouthpiece as deeply and rapidly as possible. PFT was performed three times with a sufficient rest period between tests to prevent hyperventilation. Forced vital capacity (FVC), forced expiratory volume in one second (FEV1), ratio of forced expiratory volume in one second to forced vital capacity (FEV1/FVC), and peak expiratory flow (PEF) values of the best trial were used in the analysis.

All data were analyzed using statistical software, PAWS 18.0 (SPSS, Chicago, IL, USA). The chi-square and independent t-test were performed to compare the children’s general characteristics (gender, age, weight, height, and body surface area), and dependent variables (truncal expansion, respiratory muscle strength, and pulmonary function) between the diplegic-CP group and the hemiplegic-CP group. Statistical significance was accepted for values of p<0.05.

RESULTS

The general characteristics of the two groups are shown in Table 1. No statistical differences in terms of gender distribution (p=0.09), age (p=0.06), height (p=0.53), weight (p=0.14), or body surface area (p=0.475) were observed between the two groups. Table 2 shows the truncal circumferences, respiratory muscle strength, and pulmonary function of the two groups. For all the independent variables, the diplegic-CP group showed lower values than the hemiplegic-CP group. The results of statistical analysis indicate that there were significant differences between the two groups in chest expansion, MIP, MEP, FVC, and FEV1/FVC, but not in FEV1.

| Table 1. General characteristics of the children with spastic diplegic and hemiplegic cerebral palsy |
|---------------------------------------------------------------|
| Group | Gender (M/F) | Age (years) | Height (cm) | Weight (kg) | Body surface area (m²) |
|-------|--------------|-------------|-------------|-------------|-----------------------|
| Diplegic-CP | 7/12 | 11.16±1.46 | 139.89±9.16 | 35.21±7.04 | 1.17±0.15 |
| Hemiplegic-CP | 7/3 | 10.10±1.29 | 137.50±10.95 | 40.00±10.24 | 1.22±0.20 |

| Table 2. Comparison of factors associated with respiratory function in the two groups |
|---------------------------------------------------------------|
| Group | Truncal circumference (cm) | Chest expansion | Waist expansion | Respiratory strength (cmH²O) | MIP | MEP | Pulmonary function (FVC, %) | FEV1 | FEV1/FVC |
|-------|---------------------------|-----------------|-----------------|-----------------------------|-----|-----|----------------------------|------|----------|
| Diplegic-CP | 4.29±1.43 | 2.06±0.88* | 25.11±10.90* | 36.37±15.54* | 1.24±0.44* | 1.06±0.37* | 89.45±12.27 |
| Hemiplegic-CP | 4.50±1.18 | 4.10±1.37 | 40.20±15.70 | 50.20±15.36 | 1.63±0.57 | 1.50±0.53 | 93.43±8.35 |

DISCUSSION

In the current study, poorer expansion of the waist, lower maximal inspiratory and expiratory pressures, and lower values of PFT were observed in the diplegic-CP group, compared to the hemiplegic-CP group. These findings indicate that the children with diplegic CP had poorer distensibility of the waist circumference, weaker strength of the respiratory muscles, and lower volumetric ventilation, when they breathed in and out with maximal voluntary effort. These results may be attributed to decreased waist mobility due to biomechanical inefficiency of the lower abdominal structure, and insufficiency of pressure and ventilation due to muscle weakness related to respiratory function.

Several prior studies have reported similar findings, indicating differences in waist expansion between diplegic...
and hemiplegic CP subjects, distinct from chest expansion\textsuperscript{13, 14}. For this reason, it has been assumed that an abdominal breathing pattern is more dominant than thoracic respiration in infants. Development of a thoracic breathing pattern begins with successful performance of segmental rolling activity and requires normal movement control of the head and upper limbs. A complex combination of thoracic and abdominal respiratory patterns are observed in normal adults, with the development of motor control in these body segments\textsuperscript{15}.

Differences in waist expansion, respiratory muscle strength, and PFT between the two groups may be due to differences in the regional proportions related to respiratory function, depending on the injured brain area. Children with spastic diplegic and hemiplegic CP are classified according to profile of motor involvement and pathologic etiology\textsuperscript{16}. Involvement of diplegic CP in the bilateral lower extremity is caused primarily by periventricular leukomalacia, whereas involvement of hemiplegic CP on one side of the body is the result of a unilateral hemispheric injury\textsuperscript{17, 18}. Therefore, diplegic CP, rather than hemiplegic CP, involves relatively more severe impairment of motor ability associated with respiratory function. Many prior studies have revealed that diplegic CP subjects show poorer performance in a variety of motor activities than hemiplegic CP subjects\textsuperscript{19–21}. Therefore, diplegic CP subjects show significantly decreased respiratory functions in terms of waist expansion, respiratory muscle strength, and pulmonary function, compared to hemiplegic CP.

CP is a major neurological disease resulting in motor and respiratory dysfunction\textsuperscript{22, 23}. In particular, the abnormal respiratory pattern induces disruption of motor development and restriction of functional daily living activities due to an incomplete basic vital function\textsuperscript{24}. Therefore, understanding of respiratory dysfunction in CP can provide good guidelines for clinical assessment and therapeutic intervention by rehabilitation specialists. We acknowledge that our study was limited by the small sample size of the hemiplegic-CP group due to the low incidence of spastic hemiplegic CP. In addition, postural control ability is one of the important factors affecting respiratory function. However, we did not consider the postural control ability of the children with CP; even when children who could walk a short distance using physical assistance or a hand-held mobility device were recruited. Therefore, further study will be needed to elucidate the relationship between respiratory function and postural control ability.

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