The Effects of Water-based Exercise on Respiratory Function in Children with Spastic Diplegic Cerebral Palsy

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Purpose: We investigated to evaluate the effectiveness of water-based exercise (WE) program on respiratory functions for children with spastic diplegic cerebral palsy (CP).

Methods: Fourteen children with spastic diplegic CP were randomly assigned, to either the experimental group (EG, n=7), or the control group (CG, n=7). Respiratory function was measured by a spirometer, a CardioTouch 3000S (Bionet, Seoul, Korea) at a chair-sitting posture. Forced vital capacity (FVC), forced expiratory volume at one second (FEV1), peak expiratory flow (PEF) were measured. The intervention program will last 8 weeks, with three 40 minutes sessions per week (24 training session). The usual care and the addition of a WE program, were compared in the CG and EG, respectively.

Results: The EG showed a significant increase in the FVC, FEV1, PEF after training (p<0.05), whereas there was no significant difference in the CP after training. In the EG, FVC increased significantly, compared to the control group (p<0.05), but not FEV and PEF.

Conclusion: These findings suggest that WE program have an effect on the respiratory function in children with spastic diplegic CP.

Keywords: Cerebral palsy, Respiratory function tests, Water based exercise

I. Introduction

Swimming and aquatic exercise programs can provide vigorous physical activity in a fun and a motivating environment. As a form of therapy, the potential benefits of an adapted aquatics program include increased cardio-respiratory endurance, gross motor skill performance, strength, and coordination, at the same time, improved swimming and water safety skills.

The properties of water, including buoyancy and hydrostatic pressure makes it easier for children to participate in aquatic programs. The buoyancy of water decreases the influence of gravity and provides increased postural support. These characteristics may allow children with cerebral palsy (CP) to exercise in water with more freedom than on land. The resistive forces of buoyancy and viscous drag permit a variety of aerobic and strengthening activities that can be easily modified to accommodate the wide ranges of motor abilities of children with CP.

The water-based exercise (WE), due to its non-weight bearing nature, is considered to be a safe and an effective alternative to land-based exercise to increase the respiratory fitness and strength. The use of weight bearing exercise may not be efficacious in improving the cardiopulmonary function in children with CP. Therefore, non-weight bearing exercise has been suggested as an alternative approach for those individuals who might find weight-bearing exercise difficult. Despite the theoretical respiratory benefit of WE, few studies have evaluated the effects of AE for children with CP. The purposes of this study were to evaluate the effectiveness...
of WE on the respiratory function in children with spastic diplegic CP.

II. Materials and Methods

1. Subjects
Fourteen children with spastic diplegic CP who met the inclusion criteria, participated in this study. The inclusion criteria were the following. (a) ages 6~10 years, (b) the ability to walk independently with or without and assistive device, (c) children were medically able to participate, (d) children did not require constant individualized attention for monitoring medical and behavior status, (e) children were able to following direction and attend during a 45-minute session, (f) children had any level swimming ability as long as they were not fearful of being a pool. They were randomly assigned to either the exercise group (EG, n=7), or control group (CG, n=7). Their mean ages was 8.7±1.1 years, and mean height was 122.0±7.5 cm, mean weight was 27.0±4.0 kg. All participants voluntarily signed a consent form prior to the experiment.

2. Experimental methods
1) Measurement
Respiratory function were measured by a spirometer, a CardoTouch 3000S (Bione, Seoul, Korea) at chair-sitting posture. The sufficient explanations and demonstrations were provided before the measurement. The plastic mouse piece was used to cover the mouth completely and the nose was pinched to prevent the in-flux or out-flux of air. If needed, a physical therapist helped children maintain a proper posture. Forced vital capacity (FVC), forced expiratory volume at one second (FEV1), and peak expiratory flow (PEF) were measured.

The children were coached through a standard forced expiratory maneuvers. The best value of the three repeated measurements was recorded.

2) Intervention
The WE program will last 8 weeks, with three 40 minutes sessions per week (24 training session). The usual care and the addition of a WE program, were compared in the CG and EG, respectively. The usual care included a standard physical therapy in the public system (hospital and rehabilitation clinic). The intervention added an exercise program in a waist-high pool of warm water (33°C). A qualified exercise leader instructed and trained the EG over a period of 8 weeks. The training program adheres to the principle of exercise prescription-specificity, progressive overload, and individualization.

The WE program is performed on six levels. Each session consists of 2~5 minutes of warming up exercises including stretching, breathing control, walking, jumping, and cycling, 20~25 minutes of WE program, including sagittal rotational, transverse rotational, longitudinal rotational, and combined rotational control, about 5 minutes of gait training, including straight gait and turning gait, and 2~5 minutes of cool down exercise with low intensity exercises.

During 8-weeks period, the CG continued their daily activities, which did not include any form of physical exercise similar to that in the program. This program was based on the Halliwick theory and modified as programmatic intervention that could be easily organized to improve trunk control in children with a spastic diplegic CP.

3) Statistical analysis
The average and standard deviation of the data and statistics of this study were calculated and analyzed using SPSS ver. 14.0 (SPSS Inc., Chicago, IL, USA). A Wilcoxon signed rank test was used to determine the statistical significance of the difference (p<0.05) before and after training within group. A Mann-Whitney U test was employed to determine the statistical significance of the difference between the EG and CG. The statistical significance was set to p<0.05.

III. Results
We studied the effects of AE on the respiratory function in the children with spastic diplegic CP. The EG showed a significant increase in the FVC, FEV1, and PEF after training (p<0.05), whereas there was no significant difference in the CG after training. In the EG, FVC increased significantly, compared to the CG (p<0.05), but not FEV and PEF (Table 1).
Table 1. Changes in dependent variables for CP children over 8-week intervention for both groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Test</th>
<th>Experimental group (n=7)</th>
<th>Control group (n=7)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (L)</td>
<td>Pre-test</td>
<td>0.63±0.22</td>
<td>0.59±0.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post test</td>
<td>0.93±0.26</td>
<td>0.65±0.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.026*</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>FEV1 (L)</td>
<td>Change</td>
<td>0.30±0.04</td>
<td>0.13±0.08</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Pre-test</td>
<td>0.59±0.18</td>
<td>0.58±0.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post test</td>
<td>0.81±0.16</td>
<td>0.63±0.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.02*</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>PEF (L/min)</td>
<td>Change</td>
<td>0.21±0.02</td>
<td>0.13±0.10</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Pre-test</td>
<td>1.0±0.20</td>
<td>1.29±0.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post test</td>
<td>1.4±0.31</td>
<td>1.28±0.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.02*</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td></td>
<td>change</td>
<td>6.78±5.67</td>
<td>0.29±0.25</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Values are number or mean ± standard deviation.
FVC: forced vital capacity, FEV1: forced expiratory volume at one second, PEF: peak expiratory flow.
Wilcoxon signed-rank test for within-group comparison (*p<0.05), Mann-Whitney U test for between-group comparison of improvements (¹p<0.05).

IV. Discussion

CP patients suffer from a high incidence of respiratory dysfunction, such as recurrent pneumonia, atelectasis, bronchiectasis, sleep apnea, chronic obstructive lung disease, and restrictive lung disease. Clinical symptoms, such as poor coughing and airway clearance, respiratory muscle weakness and kyphoscoliosis are thought to be related to respiratory dysfunction in these individuals. WE is an attractive form of exercise for children with CP because of the unique properties of water that may reduce risks associated with joint loading, and may allow a child to engage more easily in strength and/or aerobic activity than land-based exercise. WE may be of particular benefit to children with significant movement limitations for whom the participation in land-based exercise may be limited. Theoretically, we can evaluate respiratory function in two ways: first, the lung needs more power for breathing through a measurement of airway resistance, and second, the lung needs more time for breathing by measuring the expiratory flow volume. Among the spirometry variables, the most frequently used measurement in children is the FEV1. It is also known that when compared to normal children, asthmatic children show reduced FEV1 and FVC, even in the absence of an asthmatic attack. In this study, the EG showed a significant increase in the FVC, FEV1, and PEF after training, whereas, there was no significant difference in the CG after training. In the EG, FVC increased significantly, compared to that of the CG, but not FEV and PEF.

Studies involving typically developing children and children with asthma report a significant improvement in aerobic capacity for children engaging in aquatic exercise two or more times a week. Hutzler et al. studied the effects of a movement and swimming program and described the significant increase in the vital capacity of the children with CP. Lee et al. compared the effect of aquatic task training and land task exercise on gait and balance ability in the stroke patients. Both group showed significant improvement. But the aquatic EG showed slightly more improvement in the in static balance, Berg balance, and upright walking tests.

We admit some limitations of the study. The primary limitation was that the subjects were not screened for metabolic problems, such as metabolic acidosis and alkalosis, which could also influence the respiratory system. Also, the sample size was much less which also would have an effect on the result of the study. In conclusion, these findings suggest that an aquatic AE program was effective for children with spastic diplegic CP. Furthermore, we support the need for additional research about the effect of AE on gait analysis or activity of daily living performance.
Author Contributions

Research design: Shin HK
Acquisition of data: Shin HK
Analysis and interpretation of data: Shin HK
Drafting of the manuscript: Shin HK
Administrative, technical, and material support: Shin HK
Research supervision: Shin HK

Acknowledgements

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References