The Effect of Weight-support Treadmill Training on the Balance and Activity of Daily Living of Children with Spastic Diplegia

Hyun-Jin Choi¹, Ki-Won Nam²
¹Department of Physical Therapy, Suncheon Pyungwha Hospital, ²Department of Physical Therapy, College of Public Health and Welfare, Dongshin University

Purpose: This is designed to study the effect of weight-support walking training through motor learning on motor functions of children with cerebral palsy, in particular their activity of daily living and balance.

Methods: Thirteen children with spastic cerebral palsy, at gross motor function classification system (GMFCS) levels III~IV, underwent treadmill walking training. It used principles of weight support, 4 times a week for 7 weeks, 10 minutes at a time, before and after neurodevelopmental physical therapy. Everyday functions were measured using Functional Independence Measure for Children (Wee-FIM). The ability to keep their balance was measured using electronic measuring equipment from good balance system and the assessment was made before and after the experiment.

Results: There were significant differences (p<0.05) between pre and post experiment levels of functional independence in everyday life, in self-care activities, mobility, locomotion and social cognition. With regard to changes in standing balance, there were significant differences before and after the experiment (p<0.05) in GMFCS level III. There was a reduction in the agitation velocity in the x- and y-axes which measures the left-to-right shaking; in GMFCS level IV, velocity moment was reduced.

Conclusion: Walking training using a treadmill can help improve the everyday activity and balance in children with spastic cerebral palsy. It can also be served as a useful purpose as a method of intervention in pediatric care.

Keywords: Cerebral palsy, Balance, Activity of daily living

I. Introduction

Cerebral palsy is defined as a non-progressive disorder in which an underdeveloped brain suffers additional lesions or deformities that lead to secondary motor disturbances and abnormal posture.¹ Children with cerebral palsy have difficulty in their daily activities and social involvement as well as bodily function, due to motor disorders and abnormal posture. In the past few years, the incidence of cerebral palsy has seen a slight increase to 2~3 children in every 1,000, and this is due to the drop in the mortality rate of extremely premature babies and the subsequent rise in the proportion of babies with cerebral palsy.² The incidence of cerebral palsy in Korea was reported to have increased to 2~3 in 1,000,³ and the prevalence of spastic diplegia in extremely premature babies, born at 32 weeks or earlier, and in babies with extremely low weight is markedly high. Therefore premature birth and low birth weight stand out as risk factors for cerebral palsy.⁴

The motor condition of children with diplegia is characterized by compromised stability of the trunk due to the contraction of lower muscles of the trunk. Furthermore in standing position, there is simultaneous contraction of extensors and flexors around the joints due to the spasticity of the lower limb extensors.⁵ Thus, children with cerebral palsy show many compensatory movements that manifest as regulation of their sense of balance in other parts of the body.⁶
Bleck\textsuperscript{7} explained that among the different types of motor skill development, including independent standing and walking, most of the motor delays are the result of inadequate balance control skills in children with cerebral palsy. This leads to malformation of joints, shortening of muscles, and impaired proprioception and vision that causes difficulties in executing balance: walking and everyday movements become a challenge due to movements that induce excessive energy consumption, instability at the trunk level and maintaining posture.\textsuperscript{8}

Balance training is an important factor in carrying out everyday movements.\textsuperscript{9} Control of balance is defined as the ability to control the musculoskeletal system relative to gravity, and to control the balance necessary for moving the center of gravity.\textsuperscript{10}

Therefore, balance training is the most important for children with cerebral palsy. It endows them with the ability to move by walking in a manner similar to normal children. Children with cerebral palsy who are able to walk can independently carry out daily functions and take on social responsibilities in the local community, unlike those on wheelchairs.\textsuperscript{11} Hence, in order to improve the walking ability, the pediatric physical therapist focuses not only on balance and enhanced muscle strength, but also on walking preparations while training to crawl, sit and stand.\textsuperscript{12}

Many studies have been attempted to carry out walking training with weight support in dynamic situations in order to teach walking skills to children with cerebral palsy.\textsuperscript{13-15} A recent study showed that a therapist could enhance the ordering of the body and joint movement through control during weight-support treadmill training using a harness.\textsuperscript{16} The harness was developed to facilitate improvement in walking in children who can walk and those without walking experience undergoing therapy. It maximally activates the extensors during the swing phase and the stance phase, and children can practice walking movements on the treadmill at a slow pace wearing the harness.\textsuperscript{17} Thus, the aim of this study is to provide walking experience to children with spastic diplegia who do not have such experience, by offering a variety of sensory stimulation. There have been many studies about walking skills for patients with spinal cord injuries and strokes but there have been only a few studies about children with spastic diplegia. There have been studies in which weight-support treadmill training was attempted for walking and standing, but there is a lack of methods that can provide systematic evidence: therefore, there is a need for a multifaceted study that attempts to use treadmill walking as a training method related to everyday life, leading to functional walking, and we aim to suggest an approach that can be used in the clinic.

II. Materials and Methods

1. Subjects and periods
This study was conducted on 13 children with spastic diplegia undergoing physical therapy at a hospital in city P for 7 weeks starting on May 21, 2012. The target children were selected according to the following criteria: 1) children medically diagnosed with spastic diplegia, 2) children capable of understanding and carrying out the researcher’s instructions, 3) children with gross motor function classification system (GMFCS) levels III~IV, 4) children whose last medical treatment, including surgery, was done 6 months earlier, 5) children who are able to stand independently with the aid of support instruments, 6) children whose guardians have consented to their participation in the study.

2. Measurements
1) Study area and experimental procedures
Thirteen children diagnosed with spastic cerebral palsy at GMFCS levels III and IV were selected and measurements were made before and after the experiment. Four times a week for seven weeks before and after physical therapy, weight-support treadmill training appropriate for the children’s walking characteristics was carried out for ten minutes. In particular, for the safety of the study target and for the correct walking experience, two therapists with three or more years of clinical experience as well as researchers supervised and supported the training. Weight-support training methods were thoroughly studied before being applied to the targets (Figure 1).

In the initial stages, the children were supported to align
lower limb extensors, trunk and pelvis; progressively, the amount of support was reduced, and when children gained confidence to increase the speed, they were allowed to use side handles that provided stability. Weight-support treadmill training is at 0% incline and the amount of weight support is controlled by the harness, starting at 55% and varying between 40~60% after the target child has adapted to weight transfer and maintenance of body alignment. Treadmill speed started at 0.5 km/h~1.0 km/h and increased gradually according to children's adaptability by 0.1 km/h progressively to suit the child's speed. As for training for weight transfer and taking feet off the ground, weight transfer was attempted with one foot at a time, to extend the pelvis, knees and trunk and stimulate weight bearing. Wee-FIM and changes in balancing ability were measure before and after the experiment. Especially center of pressure (COP) changes of Good Balance System were measured by providing walkers for children having difficulties in standing.

2) Measuring apparatus and method
(1) Functional Independence Measure for Children (Wee-FIM)
Wee-FIM is a modified version of FIM, developed to test the degree of functional independence in normal children between 6 months and 7 years, as well as developmentally impaired children between 6 months and 12 years, and children with mental age of under 7 years. This test comprises a total of 18 assessment criteria, including six major criteria of self-care, control of the sphincter, mobility, locomotion, communication and social cognition; each criteria has seven levels. The purpose of this tool is to assess the ability for target children to perform daily activities in an independent manner. Wee-FIM has a high confidence and validity, with a confidence level of 0.72~0.99.

(2) Good Balance System
In this study, we used Good Balance System (Metitur Ltd., Jyväskylä, Finland) which calculates the moving trajectory of COP, known to be the measurement which mostly broadly quantifies balancing ability. The method is as follows. Both feet are placed on the triangular footboard, and forces acting perpendicular to the feet are measured. The average velocity in x- and y-axes, as well as velocity moment and the change in weight support are shown on the computer. Using the test-test method, a high confidence has been demonstrated, with intraclass correlation coefficient of 0.83. The average velocity of the COP in the x- and y-axes, was measured in mm/s as the left-to-right and front-to-back shaking distance while stationary for 30 seconds with eyes open. The velocity moment relative to the course, was measured in mm²/s 3 times and averaged.

(3) Gross Motor Function Classification System (GMFCS)
This is an equipment that measures the motor impairment of children with cerebral palsy at functionally limited levels. Children with cerebral palsy were grouped into 5 age groups (under 2, 2~4, 4~6, 6~12, and 13~18), and the degree of impairment was categorized into five levels in each age group. In this study, we targeted level III children, who can walk short distances with support and have difficulty walking in the local community, and level IV children, who have limited self-mobility and move on wheelchairs in the local community. The interobserver confidence of GMFCS is 0.96, and test-test confidence is 0.79.

3. Data analysis
In this study, weight-support treadmill training was performed, and its effects on Wee-FIM and Good Balance System...
were measured before and after the experiment. Spapiero-Wilk testing assumption was made in order to look into general characteristics and normal distribution of all subjects. As a result, normal distribution proved to be right and paired t-test was executed according to the characteristics of the study variables. \( \alpha \) was set to be 0.05 in order to assess statistical significance. Collected data were analyzed using Windows SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA).

III. Results

1. Target characteristics
This study was conducted on 13 children with spastic diplegia. Their average age was 7.0±2.2; the average height was 103.3±34.1 cm and the average weight was 22.1±8.7 kg. There were 7 GMFCS level III children, and 6 GMFCS level IV children among the targets that satisfied the above criteria and agreed to participate in the study (Table 1).

2. Changes in functional independence level in everyday life
In functional independence level in everyday life, GMFCS level III children showed significant differences changes from 31.14±4.14 to 33.71±3.30 in self-care activities, from 13.00±2.10 to 14.14±2.51 in mobility, from 8.86±1.46 to 9.57±1.51 in locomotion and from 17.43±2.99 to 18.14±2.85 in social cognition (\( p < 0.05 \)) (Table 2); GMFCS level IV children showed significant differences in changes from 28.67±6.89 to 30.00±6.63 in self-care activities and from 7.67±2.58 to 8.67±1.97 in locomotion (\( p < 0.05 \)), with an increase in average movement that was not significant (\( p > 0.05 \)) (Table 2).

3. Balance assessment (Good Balance System)
In the standing balance of GMFCS level III children, there was a reduction in the agitation velocity in the x- and y-axes, which measures the left-to-right shaking, after the experiment, with a statistically significant difference before and after (\( p < 0.05 \)). Additionally, the velocity moment decreased on average but this was not statistically significant (\( p > 0.05 \)) (Tables 3, 4). In the standing balance of GMFCS level IV children, there was a reduction in the average

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Table 1. General characteristics of subjects

<table>
<thead>
<tr>
<th>GMFCS level</th>
<th>N=13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (male/female)</td>
<td>9/4</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>7.00±2.24</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>103.25±34.13</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>22.10±8.66</td>
</tr>
<tr>
<td>GMFCS level III</td>
<td>7</td>
</tr>
<tr>
<td>GMFCS level IV</td>
<td>6</td>
</tr>
</tbody>
</table>

Values are presented as number or mean±standard deviation. GMFCS: gross motor function classification system.

Table 2. The comparison of Wee-FIM between pre and post test (unit: score)

<table>
<thead>
<tr>
<th>GMFCS level</th>
<th>Item</th>
<th>Pre test</th>
<th>Post test</th>
<th>( t )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>III (n=7)</td>
<td>Self-care</td>
<td>31.14±4.14</td>
<td>33.71±3.30</td>
<td>-3.28</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>Sphincter control</td>
<td>11.85±1.57</td>
<td>12.14±1.68</td>
<td>-1.54</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Mobility</td>
<td>13.00±2.10</td>
<td>14.14±2.51</td>
<td>-3.36</td>
<td>0.02*</td>
</tr>
<tr>
<td></td>
<td>Locomotion</td>
<td>8.86±1.46</td>
<td>9.57±1.51</td>
<td>-2.50</td>
<td>0.05*</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>11.43±2.94</td>
<td>12.43±1.62</td>
<td>-1.44</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Social cognition</td>
<td>17.43±2.99</td>
<td>18.14±2.85</td>
<td>-2.50</td>
<td>0.05*</td>
</tr>
<tr>
<td>IV (n=6)</td>
<td>Self-care</td>
<td>28.67±6.89</td>
<td>30.00±6.63</td>
<td>-3.16</td>
<td>0.03*</td>
</tr>
<tr>
<td></td>
<td>Sphincter control</td>
<td>13.50±0.84</td>
<td>13.83±0.98</td>
<td>-1.58</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>Mobility</td>
<td>11.17±5.91</td>
<td>11.67±5.39</td>
<td>-1.00</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Locomotion</td>
<td>7.67±2.58</td>
<td>8.67±1.97</td>
<td>-3.87</td>
<td>0.01*</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>12.17±1.47</td>
<td>12.67±1.51</td>
<td>-2.24</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Social cognition</td>
<td>18.17±2.14</td>
<td>18.50±1.87</td>
<td>-1.58</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. GMFCS: gross motor function classification system. *\( p < 0.05 \).

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agitation velocity in the x- and y-axes, which measures the left-to-right shaking, after the experiment, but this was not statistically significant (p > 0.05); the velocity moment decreased significantly after the experiment relative to before (p < 0.05) (Table 3, 4).

### IV. Discussion

This study was conducted to investigate the effect of weight-support walking training through motor learning on motor functions of children with cerebral palsy, in particular their activities of daily living and balance. With regard to their everyday functional independence, there were significant changes in their self-care activities, mobility, locomotion, and social cognition before and after the experiment in GMFCS level III. There were also significant changes in self-care activities and locomotion in GMFCS level IV children. In the standing balance of GMFCS level III children, there was a reduction in the agitation velocity in the x- and y-axes, which measures the left-to-right shaking, after the experiment, and for GMFCS level IV children, the velocity moment decreased.

Day et al.\(^{24}\) reports that there were improvements in the movement, the ability to move, and everyday movements after at least 25 weeks of partial weight-support treadmill moving training using Pediatric Evaluation of Disability Inventory. Begnoche et al.\(^{25}\) found that four weeks of traditional physical therapy and partial weight-support treadmill training led to an increase in self-care activities and movement which has a big effect on enhanced walking and functional exercises. Such studies seem to have targeted similar groups of children as we have done in this study, leading to similar results. Especially this study showed noticeable improvements in social cognition in GMFCS level III children and self-care activities and locomotion in GMFCS level IV children. It showed a big difference in that they made remarkable progress in social cognition and increased independence of daily activities.

The impact of therapy will be maximized if weight-support walking training could be given to spastic diplegic children who lack independence; offering a variety of experiences will increase their independence in everyday activities that have implications in their involvement in the local community and school.

For children with cerebral palsy, control of balance is clinically very important; in particular, balance control while standing can cause highly important changes in their life, allowing them to perform everyday movements. Murray et al.\(^{27}\) suggests that improved stability while standing has a large impact in walking, and Liao et al.\(^{28}\) report that children with spastic diplegia have impaired balance control while standing and impaired dynamic and stationary balance while walking, leading to a slower pace of walking compared to unaffected children. Kang\(^{29}\) has shown that children with spastic diplegia, who are able to stand but have difficulty walking, have increased shaking distance and speed of their COP, which measures their control of balance while standing, relative to unaffected children. This is due to damages to the central nervous system and imbalance in posture, leading to a changed order to muscle contraction, with distal muscles contracting before proximal muscles\(^{30}\).

### Table 3. The comparison of balance-x, balance-y, between pre and post test (unit: mm/s)

<table>
<thead>
<tr>
<th>GMFCS level</th>
<th>Pre test</th>
<th>Post test</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>III (n=7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance-x</td>
<td>9.20±1.69</td>
<td>7.19±1.17</td>
<td>6.19</td>
<td>0.00*</td>
</tr>
<tr>
<td>Balance-y</td>
<td>10.01±1.38</td>
<td>8.03±1.70</td>
<td>5.06</td>
<td>0.00*</td>
</tr>
<tr>
<td>IV (n=6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance-x</td>
<td>7.82±2.91</td>
<td>5.74±3.31</td>
<td>1.58</td>
<td>0.17</td>
</tr>
<tr>
<td>Balance-y</td>
<td>6.09±2.92</td>
<td>5.55±3.05</td>
<td>0.81</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. GMFCS: gross motor function classification system.

\(*p<0.05\).

### Table 4. A comparison of VM between pre test and post test (unit: mm²/s)

<table>
<thead>
<tr>
<th>GMFCS level</th>
<th>Pre test</th>
<th>Post test</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>III (n=7)</td>
<td>13.71±8.79</td>
<td>10.10±6.23</td>
<td>2.19</td>
<td>0.07</td>
</tr>
<tr>
<td>IV (n=6)</td>
<td>17.44±4.57</td>
<td>11.83±1.76</td>
<td>3.04</td>
<td>0.03*</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation. VM: velocity movement, GMFCS: gross motor function classification system.

\(*p<0.05\).
and reduced cooperative contraction between agonistic and antagonistic muscles. Shin also reports that walking training leads to significant differences in walking speed and balance control, and Han reports improved walking speed, balance and gross motor functions using the treadmill in task-oriented training. Gough notes that research into posture assessment is actively being conducted which attempts to intervene in musculoskeletal disorders to prevent malformation and increase functional efficiency, and that research into control of balance while standing and walking are being conducted out of a need for scientific evidence that supports an understanding and treatment of cerebral palsy and a program which manages posture regulation. Moreover, Ng and Shepherd argues that walking functions are maximally improved when dynamic movements are combined with functional movements that utilize all muscle groups. Therefore, these previous studies prove the relationship between the ability to walk and the ability to balance, supporting our results by showing that the latter can be enhanced by improving the former. The subjects were children who were capable of standing without any aids in the previous study but this study focused on the children who can stand with the help of aids. Thus, additional studies are required to be done this with a larger number of children over a longer time frame. We speculate that weight-support walking training had an effect on their body balance and weight transfer, impacting their balance recovery. Moreover, study of aquatic therapy in stroke patients by Park shows a reduced left-to-right and front-to-back posture shaking velocities. The reduction in the shaking velocity in x- and y-axes was similar to previous studies and was significant showed decrease in GMFCS level III and velocity movement decreased in GMFCS level IV. Lee et al. also reports that training after measuring balance control with eyes open led to a significant difference. This is similar to our study in that it provided weight-support walking training to spastic diplegic children who are unable to walk, offering increased sensory stimulation of the lower limbs and self-experience of movement, leading to improved balance and daily activities.

The present study has shown that weight-support treadmill training is effective in improving independent daily activities and balance in children with spastic diplegia, and suggests that it should be considered as a dynamic walking training as part of their physical therapy program. However, there is currently inadequate research on weight-support treadmill training in children with cerebral palsy. Thus, in order to effectively apply it to children with cerebral palsy, there needs to be more research in a variety of angles, including the change in speed, change in lower limb muscle activity, and the effect on their walking, to allow diverse approaches that can suit each child characteristics. Therefore, the present study suggests that weight-support treadmill training is effective for children with spastic diplegia who are unable to walk, and prompts further studies to look into a variety of methods that can suit the characteristics of different children and which provide quantitative evidence of treadmill training as a quantitative assessment tool.

The limitation of the present study is that, due to a small number of study targets and a focus on spastic diplegia that prohibits independent walking, it cannot represent the entire population of children with cerebral palsy. It would have been better if there had been control group conducted on general neurodevelopmental treatment. But there were some difficulties in finding out subjects with related characteristics and environmental design. Hence, additional weight-support treadmill training was done for children who made a slow progress in measurement categories. Moreover, the effects of therapeutic intervention outside the hospital could not be controlled by the study method.

References

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