Effect of Backward Walking Training on Dynamic Balance in Children with Spastic Hemiplegic Cerebral Palsy

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Purpose This study aimed to investigate changes in dynamic balance after backward walking training in children with spastic hemiplegic cerebral palsy. **Methods** To control potentially confounding variables and to assess the immediate effect of backward walking training, the same exercise was repeated once over a 20-minute period. The Single Leg Standing Test (SLS), Symmetry Ratio (SR), Timed Up and Go Test (TUG), Timed Stair Climbing Test (TSC) scores were collected and analyzed using the Wilcoxon rank sum test. **Results** There was no significant increase in single leg standing time on the less affected side ($p>0.05$). However, single leg standing time on the affected side, the symmetry ratio, the timed up and go test and timed stair climbing test were significantly increased ($p<0.05$). **Conclusion** Our results suggest that, backward walking training can be usefully applied as a programs to improve the dynamic balance of children with spastic hemiplegic cerebral palsy.

Key words Backward walking, dynamic balance, cerebral palsy, hemiplegia, walking ability

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I. Introduction

Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitations that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behavior; by epilepsy, and by secondary musculoskeletal problems.[1] The most common type of cerebral palsy is the spastic type, and there are many problems that arise due to kinematic and kinetic changes. Muscle growth is slower than bone growth in spastic cerebral palsy. During growth, joint construction transforms.[2] Postural control is essential to perform all levels of tasks from infancy through adulthood.[3] Furthermore, problems with dynamic balance are common in children with cerebral palsy[4] and include inappropriate muscle organization, abnormal intersensory integrative ability and late onset of muscle activation.[5] During walking, children with spastic hemiplegic cerebral palsy have poor motor coordination, which results in a short stride, increased stride frequency to maintain speed, increased swing, and poor stability due to center-of-gravity fluctuations.[6] Hemiplegia also affects performance on balance tasks during standing in children.[7] Consequently, children with cerebral palsy consume more energy for limited activity.[8] Therefore, dynamic stability is essential for walking ability. Gait rehabilitation with backward walking emphasizes positioning the foot behind the body and thus facilitates hip extension while performing a knee flexion that can be useful for patients who have synergistic influences in the lower extremity.[9] A longer period of leg-muscle activity during backward than during forward walking training can result in greater muscle strength gain.[10] Backward walking is used as one of the rehabilitation methods for orthopedic or neurosurgical patients, particularly to improve muscle strength and balance, which is an advantage of backward movement.[11] Backward walking training

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may help to improve walking abilities and other gross motor skills.[12] Amr Almaz et al. found that traditional physical therapy with backward walking training is more effective than is a traditional physical therapy program that focuses on postural stability in patients with spastic hemiplegic cerebral palsy.[13] Therefore, the purpose of this study was to evaluate the effectiveness of backward walking training on dynamic balance in children with spastic hemiplegic cerebral palsy.

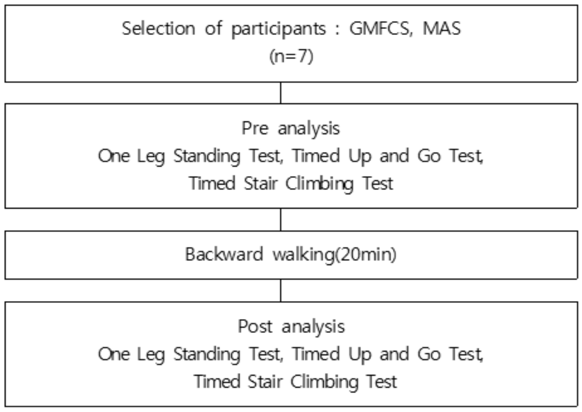

Figure 1. Study Flow chart

II. Materials and Methods

1. Participants

The subjects of this study were patients diagnosed with spastic hemiplegic cerebral palsy at S university hospital in Seodaemun-gu, Seoul, Korea. We enrolled children who could walk independently or with assistive devices; children with motor dysfunction graded as a 1 or 2 on the Gross Motor Function Classification System (GMFCS); and children scoring 1, 1+, or 2 on the Modified Ashworth Scale (MAS). (Table 1)

2. Study design

This study was performed by a physical therapist at S Hospital in Seodaemun-gu, Seoul, Korea. To control potentially confounding variables and to assess the immediate effect of backward walking training, the same exercise was repeated once for 20 minutes. The degree of support varied in accordance with the child's walking ability. We used the one leg standing test, the timed up and go test, and the timed stair climbing test to assess function before and after treatment. (Figure 1,2,3,4)

Table 1. Demographic characteristics.

Variables	Mean±SD, n=7
Sex (M/F)	6(85.71%)/1(14.29%)
Age	6.60±2.18
Height (cm)	115.57±9.62
Weight (kg)	21.00±7.35
Hemi-side (Rt/Lt)	4(57.14%)/3(42.86%)
GMFCS	1.00±0.00
MAS	1.36±0.38

Figure 2. Pelvic support

Figure 3. Hand support

Figure 4. Head guide

3. Instrument

1) Instrument of subject selection

(1) Gross Motor Function Classification System (GMFCS)

The Gross Motor Functional Classification System is a standardized tool to measure movement disorders in children with cerebral palsy at the functional limit level. The evaluation criteria are applied differently according to age, while the degree of disability is divided into four stages based on age: 0-2 years, 2-4 years, 4-6 years, and 6-12 years. The subjects were divided into two groups based on the level of ability (levels I-V): children with walking ability (levels I, II, and III) and those without walking ability (levels IV and V).

(2) Modified Ashworth Scale (MAS)

Modified Ashworth Scale has been used as the most common method of measuring muscle tension. When passive stretching is applied to a specific muscle, it is a method to measure the score by dividing the range according to the condition of muscle tension increase.

2) Instrument of balance

(1) Single Leg Standing Test : SLS

The single leg standing test is a simple and effective test to assess static balance. It is conducted by measuring the time that a child can maintain balance by lifting a pair of feet according to the signal "Start." The average of three measures was used. (Figure 5)

(2) Symmetry Ratio : SR

$$\text{Symmetry ratio: SR} = \{1 - \frac{\text{Affected side}}{\text{Non-affected side}}\}$$

An SR score 0 indicates more symmetrical one leg standing.

(3) Timed Up and Go Test : TUG

The timed up and go test was used to evaluate the dynamic balance and ability to rotate and move among study subjects. The adjust table was used. After sitting on the adjust table, subjects walked for 3 m on a flat surface and then returned to the table. We measured the time required to return to the adjust table. The subject can practice several times. (Figure 6)

(4) Timed Stair Climbing Test : TSC

The timed stair climbing test is a variation of TUG. It was used to evaluate dynamic balance and the ability to rotate and move among study subjects. The adjust table was used. After sitting on the adjust table, subjects climbed up stairs and then returned. We measured the time required to return to the adjust table. The subject can practice several times. (Figure 7)

4. Statistical analysis

The Wilcoxon ranked-sign test. was used to examine the difference in symmetry with SLS test and used to determine dynamic balance with TUG test, TSC test. The collected data were analyzed using a Statistical Package for Social Science (SPSS version 20). A probability of $P<0.05$ was considered to be statistically significant.

III. Results

1. SLS Test

There was no significant increase in the less affected

Figure 5. Single Leg Standing

Figure 6. Timed Up and Go

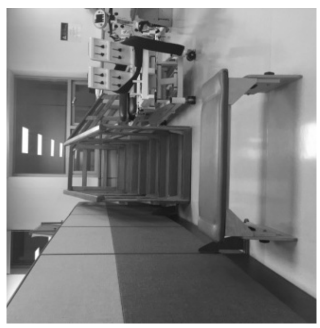

Figure 7. Timed Stair Climbing

side: 6.71 seconds to 7.83 seconds (p>0.05). However, there was a statistically significant increase (2.29 seconds before training to 4.93 seconds after training) in the affected side (p<0.05). (Figure 8)

2. Symmetry Ratio (SR)

The SR of the affected and less affected sides increased significantly from 67.71% to 32.29%, compared with that before and after backward walking training (p<0.05). (Figure 9)

3. Dynamic balance (TUG Test and TSC Test)

In the TUG test, there was a significant increase from 12.64 seconds before training to 10.21 seconds after training (p<0.05). (Figure 10)

In the TSC test, there was a significant increase from 17.64 seconds before the training to 14.86 seconds after training (p<0.05). (Figure 10)

IV. Discussion

This study sought to investigate the changes in dynamic balance after backward walking training in children with spastic hemiplegic cerebral palsy. There were improvements in the single leg standing test, static balance, and symmetry ratio after backward walking training. This result was similar to that of a study by Zhang who evaluated a single leg standing test after treating an 18-year-old girl with backward walking training for 12 weeks. The single leg standing test showed that the group that underwent therapy with backward walking increased balance ability compared to the control group. Furthermore, the center of gravity during static standing with the subjects' eyes closed in the experimental group was much smaller than in the control group.[14] In some studies, treadmill walking training produced an increase in the walking speed and symmetry ratio. It has been speculated that such training provided visual and proprioceptive stimuli to patients with chronic stroke.[15] Westcott showed there are three primary systems that contribute to the balancing process. First, the sensory system (visual, cutaneous and proprioceptive, and vestibular senses) provides feedback to alter balance during a voluntary motor task. Second, the motor system creates the coordination movement to maintain balance. Third, the biomechanical/musculoskeletal system includes the muscles that create the movement torques and the bones and joint frame on which movements are made.[4] All three systems may be associated with an improvement in balance by backward walking training. Furthermore, oxygenated hemoglobin was found to be increased in the supplementary motor area, precentral gyrus, and superior parietal lobule when participants walked backwards rather than forwards. This suggested that backward walking presents more of a stability challenge than does forward walking.[16] Previous studies have shown that backward walking improves hamstring and quadriceps muscle strength. In addition, muscle activity is higher during backward than during forward walking because of lower extremity EMG(Electro Myo Graphy).[17] Kramer and Reid analyzed the mechanical and physiological benefits of backward and forward walking, and found that backward walking training increased the lower

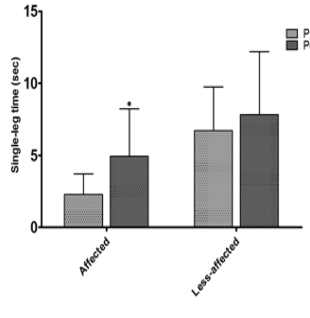

Figure 8. Single Leg Standing

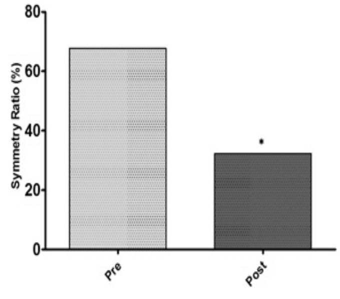

Figure 9. Symmetry Ratio

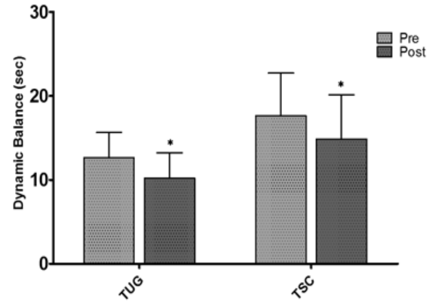

Figure 10. Dynamic Balance

extremity muscle activity over a longer period of time and that this activity contributes to greater strength.[10] Hao and Chen found that backward walking training improved the balancing ability of a healthy 16-year-old child. They found that reorganization of the muscle synergies, neuromotor control during backward walking, and changes in muscle strength in the lower extremity may contribute to the improvement in balance.[18] It can be interpreted that improvements in walking speed are due to the dynamic balance, which is the ability to correct posture due to the strengthening of the lower extremity muscles. Therefore, backward walking training will improve the dynamic balance of children with spastic hemiplegic cerebral palsy. This study has the following limitations. First, we recruited only a small number of patients. Second, the lack of follow-up in children prevented us from truly evaluating the persistence of the effects of backward walking training. Third, we did not assess muscle strength and energy expenditure. Fourth, each child walked at a comfortable speed, which differed among children. Future studies with a larger number of children with cerebral palsy are required to assess the significance of the effects of backward walking training. Moreover, future studies should include electromyographic studies to record the effect of additional backward walking training on muscular activities in these children.

V. Conclusion

Muscle strength and balance improved following training with backward walking, thereby resulting in increased static stability. Symmetry and dynamic balance during walking increased as static stability increased, which affected the walking speed and time reduction in TUG and TSC tests. It is believed that backward walking training can be usefully applied as a type of therapy to improve the dynamic balance of children with spastic hemiplegic cerebral palsy.

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