The Approach of Robot-assisted Gait Therapy for Locomotor Recovery of Chronic Stroke Patients: a Case Report

In this case report, we investigated the effects of robot-assisted gait therapy in a chronic stroke patient using motor assessment and gait analysis. A patient who suffered from the right hemiparesis following the left corona radiata and basal ganglia infarction received 30 minutes of robot-assisted gait therapy, 3 times a week for 4 weeks. Outcome was measured using Motoricity index(MI), Fugl-Meyer assessment(FMA), modified motor assessment scale(MMAS), isometric torque, body tissue composition, 10-meter gait speed and gait analysis. After robot-assisted gait therapy, the patient showed improvement in motor functions measured by MI, FMA, MMAS, isometric torque, skeletal muscle mass, 10-meter gait speed. In gait analysis, cadence, single support time, double support time, step length, walking speed improvement in after robot-assisted gait therapy. The results of this study showed that robot-assisted gait therapy is considered to facilitate locomotor recovery of the chronic hemiparetic stroke patient.

Key words: Robot-assisted Gait Therapy; BWSTT; Gait; Stroke; Lokomat

INTRODUCTION

The recovery of gait function is one of the most important aims for patients with injured central nervous system such as stroke, spinal cord injuries, and traumatic brain damage. It is a major factor influencing return to home or work(1). For patients with gait problems due to stroke, neurophysiological treatment concepts in other words, traditional treatment such as Bobath, PNF, Brunstrom, and Vojta have been applied. However, recently based on the motor learning concept, treatments enabling patients to learn motor skills through task-specific training involving repetition of movements that are most similar to motions ultimately wanted by patients have been highlighted(2). Body weight-supported treadmill training(BWSTT) is a representative treatment example based on this motor learning theory.

BWSTT focuses on ideal kinematics as well as time aspect when walking and is based on training for normal physiological walking patterns(3, 4, 5). A patient may supplement deficits in equilibrium responses by wearing a harness, complement deficits from paresis of the legs through weight support, and resistant walking with motor-driven treadmill(6).

There have been reports from systematic analyses that gait functions of patients with neurological damage such as stroke or spinal cord injuries have improved(7, 8). Also there have been reports that compared to traditional therapeutic exercise, BWSTT has shown similar effects to improve gait and motor function(9) while some reports have maintained that in experiments on control cortex and spinal cord by motor learning and task-specific training, the task-specific training has been more effective than traditional therapeutic exercise(10, 11).

However, in order to help patients with gait problems to receive repetitive gait training safely based on the application of normal gait patterns, physical
therapist’s physical efforts and time as well as a few skilled physical therapists will be necessary. At the same time, there is a problem that reproducibility of gait may be reduced according to the level of skills of physical therapist’s. As for patients with excessive muscular loss and involuntary movement due to extensive damage, free walking training will be almost impossible. In order to overcome this limit, recently, a robot–driven gait orthosis has been developed(Fig. 1).

The robot–assisted gait therapy(RAGT) enables tailor–made treadmill gait training by inducing a patient’s legs movement according to pre–programmed normal physiological gait pattern. It can be applied to patients with severe so it is highlighted as an effective gait treatment tool. Recently, the impact of robot–assisted gait therapy on stroke patients has been reported(12).

This case report aimed to identify how robot–assisted gait therapy can contribute to recovery of leg movement and gait functions as an assistive method of physical therapy for neurological patients by applying a robot–driven gait orthosis to chronic stroke patients and analyzing motor and gait functions before and after the treatment, resulting in motor disturbances from right hemiplegia(Fig. 2). For this patient, palliative motor treatment took place from April 10. While the patient visited S Hospital in Seoul, gait training using a robot–driven gait orthosis was provided 12 times for four weeks, three times a week from April 2, 2008. While robot–assisted gait therapy took place, palliative rehabilitation treatment except for gait training was provided and the onset duration was 24 months.

As for the functional level, the range of motion of right arms and legs was with in normal limits(WNL) and the manual muscle test resulted in 3 on average (Fair+) while spasticity was 1 on average. The static balance was Good grade while dynamic balance was Fair grade. The functional ambulation category (FAC)(13) evaluating based on the range of 0–5 according to the level necessitating assistance when walking was 5.

The gait pattern was of circumduction gait and in the swing phase, single support time of the paralyzed leg as well as flexion of hip and knee joints was reduced. Upon the initial contact, there was a tendency of inversion of the ankle on the paralyzed side.

![Fig. 1. Robot–driven gait orthosis](image)

**CASE REPORT**

**Patient**

This patient, aged 46, was diagnosed on April 8, 2006 of infarction in corona radiata and basal gan-

**Fig. 2.** Brain MRI of the patient showing a infarction in left cerebral hemisphere

**Assessment**

Before and after the implementation of gait training using a robot–driven gait orthosis, motor functions were tested for each case after four weeks. All the tests were conducted one skilled physical therapist(7 years of experience).

**Assessment of motor functions**

The test items consisted of motoricity index(MI)(14) applying manual muscle testing of leg muscles and...
assessing between 1–100 marks, Fugl–Meyer Assessment (FMA)(15) assessing between 0–34 marks according to the recovery level of leg muscles, modified motor assessment scale (MMA)(16) assessing motor functions of parts except for arms between 0–36 marks, skeletal body mass produced through Inbody720®(Bio–space Co, Ltd, Seoul, Korea), and isometric torque measuring with test programs of the Lokomat® driven gait orthosis(Hocoma AG, Zurich, Switzerland).

Assessment of gait function
A 10-meter gait on the flat land took place for speed measurement and Vicon 612 motion analysis system(©Oxford Metrics Ltd, Oxford, UK) with five infrared cameras was applied for gait analysis and measurement of gait indexes.

Robot–assisted Gait Therapy
As for the robot–driven gait orthosis, Lokomat® was used. Lokomat® consists of a robot–assisted instrument to control postures and a weight support gait instrument. It works while connected to a treadmill(Woodway GmbH, Weil am Rhein, Germany) (Fig. 3). As a patient wears a harness attached to the weight support so that the patient can safely stand on the treadmill. The gait control instrument is a computer–controlled robot. A patient may wear adjusting it to correspond to the locations of hip and knee joints, It was devised to control leg movement according to gait speed. When the treadmill works while a patient is lifted through the weight support and robot–driven gait orthosis, the patient will be descended over the treadmill to adjust the weight support level, Then the robot–assisted gait programmed according to normal physiological gait patterns will begin. According to gait patterns, the computer will properly adjust the treadmill speed, joint motion speed and angle, and level of weight support of the weight support instrument.

The robot–driven gait orthosis may be used to reduce Lokomat guidance force. More reduction will induce more active movements of the patient. In this study, 100% application took place at the early stage of training and the guidance force was reduced to 60% according to the patient’s adaptation and gait patterns, Also the weight support began at 40% at the early stage of training.

In the third week, it was reduced to 20% and in the fourth week, it was again reduced to 10% before the closure of the training. The gait speed on the treadmill started at 1.2 km/hr, which was increased to 2.4 km/hr.

In the first week, manual gait training was applied to help the patient to adapt to the robot–driven gait orthosis and to learn normal gait patterns. From the second week, resistance training and active normal gait patterns were provided. As for biofeedback, in the first and second weeks, patterns of hip and knee joints of both legs were shown for comparison. In the third and fourth weeks, only the flexion of hip and knee joints at the swing phase of the paralyzed leg was shown for concentration. The patient’s step length was increased and the motion range of the hip joint was gradually increased from 40° at the earlier stage to 45° to increase the single support time of the paralyzed foot.
All the indexes were gradually adjusted based on the improvement of the patient’s muscular strength and gait capacity. As for the time length for robot-assisted gait therapy, the actual treatment was provided 30 minutes a day except for computer adjustment time. It took place 12 times for four weeks, three times a week.

**Result**

**Changes in clinical indexes of motor functions**

After gait treatment using a robot–driven gait orthosis, isometric force of flexor and extensor muscles in hip and knee joints of the paralyzed leg improved. Grades of MI, FMA, and MMAS also improved. The skeletal muscle mass of the paralyzed leg also increased after treatment(Table 1).

<table>
<thead>
<tr>
<th>Assessment item</th>
<th>Before</th>
<th>After</th>
<th>F/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isometric torque(Nm) (affected lower limb)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip flexor</td>
<td>72.6</td>
<td>109.1</td>
<td>103.1</td>
</tr>
<tr>
<td>Hip extensor</td>
<td>93.8</td>
<td>106.9</td>
<td>102.6</td>
</tr>
<tr>
<td>Knee flexor</td>
<td>42</td>
<td>57.6</td>
<td>68.5</td>
</tr>
<tr>
<td>Knee extensor</td>
<td>75.2</td>
<td>97.8</td>
<td>89.2</td>
</tr>
<tr>
<td>MI</td>
<td>70</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>FMA score</td>
<td>27</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>MMAS</td>
<td>33</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Skeletal muscle mass</td>
<td>36.9</td>
<td>37.5</td>
<td>37.2</td>
</tr>
</tbody>
</table>

**Table 1. Motor function before and after the robot-assisted gait therapy**

**Changes in clinical indexes of gait functions**

1. **Gait analysis**

   Based on changes in temporal gait parameters, double support time and cadence of paralyzed and non–paralyzed legs decreased after training while single support time of the paralyzed leg, step length, and gait speed improved after treatment(Table 2).

   As for changes in kinematic indexes, changes in the maximum flexion movement of hip joints improved while changes in the maximum flexion of knee joints and the minimum flexion movement of knee joints improved. Changes in the maximum dorsiflexion movement of ankle joints became better after training(Fig. 5).

   **Table 2. Assessment of temporal gait parameters before and after the robot-assisted gait therapy**

<table>
<thead>
<tr>
<th>Item</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadence(step/min)</td>
<td>81.26</td>
<td>73.47</td>
</tr>
<tr>
<td>Single support time(%cycle)</td>
<td>20.09</td>
<td>25.15</td>
</tr>
<tr>
<td>Double support time(%cycle)</td>
<td>37.42</td>
<td>36.03</td>
</tr>
<tr>
<td>Step length(m)</td>
<td>.34</td>
<td>.38</td>
</tr>
<tr>
<td>Walking speed(m/s)</td>
<td>.41</td>
<td>.46</td>
</tr>
</tbody>
</table>

2. **10 meter gait speed**

   In the 10–meter gait speed test, the speed improved after the robot–assisted gait therapy. In the follow–up test after four weeks, it was found that the improved speed was maintained(Table 3).

   **Table 3. 10 meter gait speed before and after the robot-assisted gait therapy**

<table>
<thead>
<tr>
<th>Assessment item</th>
<th>Before</th>
<th>After</th>
<th>F/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–meter gait speed(m/sec)</td>
<td>.51</td>
<td>.67</td>
<td>.69</td>
</tr>
</tbody>
</table>
**DISCUSSION**

Recently, the importance of motor learning in the recovery process after brain damage is highlighted. As for the recovery mechanism after brain damage, true recovery and compensation of damaged brain is known to affect[17]. The true recovery of brain means reorganization of brain replacing the function damaged by neuroplasticity while the compensation is to use other muscles instead of paralyzed muscles to provide an aimed movement. Changes in cerebral cortex based on true recovery of brain do not occur from repetition of simple motions. But there is a report that it is generated through acquisition of new motor skills[18]. Compensation for motor paralysis takes place through repetitive motor learning.

Therefore, the recovery mechanism after brain damage caused by process of motor learning can be seen[17]. The important part in motor learning includes motor skill acquisition, motor adaptation, and decision making. The motor performance will improve based on the amount of training[19]. The representative gait treatment based on this motor learning theory is the body weight support treadmill training. Generally, it is known to have advantages of balance and improved stability of both legs, inhibition of unnecessary muscle tone due to fear of fall, early experience of gait, and improved gait patterns[6, 20, 21]. The Lokomat® driven gait orthosis applied for this case can be clinically useful in that it has strengthened advantages of body weight support treadmill training, instead of a simple joint training exercise in behavior based on learning theory, the final

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*Fig. 5. Assessment of kinematics gait parameters before and after the robot–assisted gait therapy*
goal of training to provide an environment similar to the actual gait, and design enabling intensive repetitive training.

Mayr et al. reported that the robot-assisted gait therapy provided more significant improvement than traditional training when Rivermead motor assessment scale evaluating motor functions and muscle strength of five leg muscles were measured in their study which implemented gait therapy by using the Lokomat® driven gait orthosis for 16 stroke patients(22). Also, in this case report, in terms of MI, FMA, MMAS, and isometric torque of hip and knee joints, there was great improvement after the robot-assisted gait therapy. This means that robot-assisted gait therapy is effective for muscle strength recovery. The increased muscle mass based on the body tissue test implemented in this case report also supports this maintenance.

Despite the fact of improvement in the stroke patient’s general conditions as well as muscular contraction, we can still find the continued deviated gait(23). With robot-assisted gait therapy, gait variables such as step length and gait speed may be adjusted according to a patient’s gait performance. It was programmed to repeat and reproduce symmetrical physiological gait patterns by extending the support of the paralyzed leg in the stable upright position from the weight support. Husemann et al. reported that after gait treatment of 30 stroke patients using the Lokomat® driven gait orthosis, single support time of the paralyzed leg significantly increased(12). In this case, based on gait analyses after robot-assisted gait therapy, single support time of the affected side increased while the support of both legs decreased. In addition, step length of both legs, cadence, and gait speed improved. Also the maximum flexion movement of hip joints as well as the maximum/minimum flexion movement of knee joints and maximum dorsiflexion of ankle joints became better. Also in the 10-meter gait speed among all other clinical gait indexes, there was improvement after robot-assisted gait therapy. Therefore, robot-assisted gait training can improve the symmetry of gait. This is considered to improve a patient’s gait performance.

This case report aimed to identify improvement of locomotor functions after providing robot-assisted gait therapy to chronic stroke patients with gait problems. When comparison took place before and after robot-assisted gait therapy, improvement in motor functions of legs as well as gait patterns was observed after training.

In this study, there was no control group. Therefore, improvement in motor and gait functions through physical therapy after brain damage and the effects of robot-assisted gait therapy could not be separated. However, based on the noticeable improvement in motor functions and gait patterns over four weeks, a short period of time, we can assume that robot-assisted gait therapy has provided great contribution. In the future, studies shall be extended for randomized controlled trial involving a robot-assisted gait therapy group and a control group. Especially, it will be necessary to apply a long-term gait training opportunity that highlights the advantages of robot-assisted gait therapy.

REFERENCES