Efficacy of the Gait Training Using Footpad-Type Locomotion Interface in Chronic Post-Stroke Patients: A Pilot Study

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Abstract

Purpose: In recent years, robotics have been used for rehabilitation. We developed a footpad-type locomotion interface using robot technology, and we reported improvement on gait speed and muscle strength. The purpose of this study was to compare the effects of gait training using a footpad-type locomotion interface (GTLI) with those of body weight support treadmill training (BWSTT).

Methods: Eleven chronic post-stroke patients participated in this study. The subjects received GTLI and BWSTT respectively three times a week for a total of 12 times. The outcome measures were maximum gait speed, timed up and go test, and isometric muscle strengths of both hip and knee flexion and extension.

Result: No differences were observed in the gait speed and timed up and go test among GTLI and BWSTT. In isometric muscle strengths, GTLI improved better than BWSTT.

Conclusion: These results suggest that GTLI and BWSTT have similar effects on improving the gait and balance abilities. In addition, GTLI is more effective in improving the isometric muscle strength of hip extension and knee flexion than using BWSTT.

Keywords: Footpad type locomotion interface; BWSTT; Chronic post-stroke

Introduction

In recent years, robotic devices such as LOKOMAT, Gait Trainer and, Hybrid Assistive Limb® have been used in rehabilitation. About them, a lot of intervention effects are reported [1-3]. A systematic review of electromechanical assisted gait training using robotic devices was effective at improving the gait ability after stroke [4]. Systematic review showed some problems. The problem included optimum training duration and frequency of electromechanical assisted gait training using robotic devices and the high cost of the robotic devices. Therefore, we developed a footpad-type, small size and low-price locomotion interface [5]. The footpad-type locomotion interface consists of two slider cranks for moving the footpads back and forth, two actuators for moving the footpads up and down, and computer for controlling their movements. The trajectories of footpads are based on healthy individual's gait trajectory. The trajectory can be scaled to any size and cycle in accord with the subject's physical ability and condition (Figure 1). As a result, patients were able to perform repetitive exercises and hip extension exercises by the footpad-type locomotion interface. The footpad-type locomotion interface is controlled by a computer program, the gait trajectories and gait speed can be easily changed. We previously reported improvements in walking speed with a footpad-type locomotion interface in chronic stroke patients [6,7]. However, we had not compared the other gait training.

Body weight support treadmill training (BWSTT) is one of the most used gait training methods in recent years. BWSTT has been reported for intervention effects and efficacy. The purpose of this study was to examine the effectiveness of gait training using a footpad-type locomotion interface (GTLI) by comparing GTLI and BWSTT.
Methods

Eleven ambulatory chronic post-stroke patients participated in this study (Table 1). Figure 2 shows the study protocol. Subjects were allocated by a computer-generated sequence into an odd number (group A) and even number (group B). In group A (n=7), the subjects underwent training using GTLI (three times a week for a total of 12 sessions) followed by that using BWST (three times a week for a total of 12 sessions), whereas in group B (n=4), the subjects underwent training using BWSTT followed by that using GTLI.

In GTLI, we used a footpad-type locomotion interface named GaitMaster developed by the Department of Intelligent Interaction Technologies, Graduate school of Systems and Information Engineering, University of Tsukuba. In BWSTT, we used a Biodex Unweighting System (Biodex Medical Systems, Shirley, NY, USA) and a Gait Training System (Biodex Medical Systems, Shirley, NY, USA).

The condition of gait training using GTLI and BWSTT was as follows: (a) gait training was 20 min once a day, (b) the gait speed set as fast as possible, (c) The subjects were able to grip the handrail. The gait speed, stride, and were controlled in accord with the subject's condition. During gait training, the subject's body movement and lower limb movement were assisted by a physical therapist as needed. In BWSTT, the amount of body-weight support was fixed at 20% in all BWSTT sessions.

We measured the maximum isometric strength for 10-sec periods. We measured two times and used the maximum muscle strength.

These measures were evaluated at once a week (Measurement, M: M1-12, Figure 2). There was a non-training period of at least 8 weeks between each training session.

For maximum gait speed, TUG and muscle strengths, we calculated the change from the pre-training. The Mann-Whitney test was used to compare the changes at post-training (M8) or 1-month after post-training (M12) of the GTLI and BWSTT and as well as the characteristics of groups A and B.

Statistical analyses were performed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at P<0.05.

This study was approved by the ethics committee of Tsukuba Memorial Hospital, and all participants or their legal representatives gave written informed consent to participate in the study.

Result

At the study onset, no differences between groups A and B were observed among the baseline clinical data, initial gait speed, initial TUG and initial isometric muscle strength (Table 2). Gait speed, and TUG of 11 subjects were analyzed. In two isometric muscle strengths could not be measured. Therefore, isometric muscle strengths of 9 subjects were analyzed.

Table 3 shows a comparison between GTLI and BWSTT in post-training, and 1-month after post-training. We found no significant difference between the GTLI and BWSTT in change in maximum gait speed at post-training (GTLI 0.13 ± 0.05 m/s versus BWSTT 0.18 ± 0.06 m/s, p=0.65), and 1-month after post-training (GTLI 0.16 ± 0.06 m/s versus BWSTT 0.12 ± 0.06 m/s, p=0.27).

Regarding change in TUG, we found no significant difference between the GTLI and BWSTT in change in TUG at post-training (GTLI -2.3 ± 0.8 seconds versus BWSTT -0.9 ± 0.6 seconds, p=0.30), and 1-month after post-training (GTLI -3.0 ± 0.9 versus BWSTT -0.9 ± 0.7, p=0.09).

As regards the isometric muscle strength, we found significant difference between the GTLI and BWSTT in paretic hip extension at post-training (GTLI 1.1 ± 0.5 kg versus BWSTT -0.5 ± 0.7 kg, p=0.01) and paretic knee flexion at 1-month after post-training (GTLI 2.3 ± 0.8 kg versus BWSTT -0.1 ± 0.7 kg, p=0.02).
We found no significant difference between the GTLI and BWSTT in change in the other isometric muscle strength at post-training and 1-month after post-training.

|                  | Group A               | Group B       |
|------------------|-----------------------|---------------|
| n                | 7                     | 4             |
| Age              | 57.9 ± 7.5            | 62.0 ± 16.3   | n.s           |
| Post-stroke interval (months) | 57.0 ± 39.6          | 24.3 ± 6.7    | n.s           |
| BRS III/IV/V     | 1/5/1                 | 1/1/2         |
| Maximum gait speed (m/s) | 0.71 ± 0.23         | 0.99 ± 0.12   | n.s           |
| TUG (s)          | 20.6 ± 7.5            | 14.3 ± 2.4    | n.s           |

| Isometric muscle strength | Paretic side (n) | Non Paretic side (n) |
|---------------------------|------------------|-----------------------|
| Hip extension             | 6.8 ± 3.3 (7)    | 6.3 ± 15.2 (2)        | n.s           |
| flexion                   | 9.1 ± 3.3 (7)    | 7.1 ± 1.9 (2)         | n.s           |
| Knee extension            | 17.3 ± 11.4 (7)  | 14.2 ± 4.0 (2)        | n.s           |
| flexion                   | 4.8 ± 4.0 (7)    | 1.2 ± 1.6 (2)         | n.s           |
| Hip extension             | 13.4 ± 4.4 (7)   | 13.8 ± 9.3 (2)        | n.s           |
| flexion                   | 16.1 ± 5.0 (7)   | 27.8 ± 3.2 (2)        | n.s           |
| Knee extension            | 28.5 ± 3.3 (7)   | 33.7 ± 3.1 (2)        | n.s           |
| flexion                   | 12.7 ± 3.3 (7)   | 16.8 ± 8.2 (2)        | n.s           |

Table 2: Clinical data and initial assessment data for both group.

Discussion

In gait speed and TUG, there was no significant difference between GTLI and BWSTT. These results show that GTLI has similar efficacy as BWSTT, which is recommended in the stroke treatment guidelines [8] in gait speed, and TUG.

|                  | Knee extensi         | Knee flexi       | Non Paretic Hip extensi | Non Paretic Hip flexion |
|------------------|----------------------|------------------|-------------------------|-------------------------|
|                  | on                   | on               | on                      | on                      |
|                  | 2.6 ± 1.8            | 2.6 ± 1.6        | 3.1 ± 1.3               | 3.1 ± 1.9               |
|                  | n.s                  | n.s              | n.s                     | n.s                     |
|                  | 0.7 ± 0.6            | 0.2 ± 1.1        | 2.3 ± 0.8               | -0.1 ± 0.9              |
|                  | p<0.05               | n.s              | n.s                     | p<0.05                  |
|                  | 2.9 ± 1.5            | 1.1 ± 0.8        | 2.0 ± 0.8               | 1.6 ± 0.9               |
|                  | n.s                  | n.s              | n.s                     | n.s                     |
|                  | 2.7 ± 1.8            | 1.8 ± 2.7        | 5.0 ± 2.4               | 2.9 ± 1.2               |
|                  | n.s                  | n.s              | n.s                     | n.s                     |
|                  | 1.5 ± 0.9            | 1.0 ± 1.1        | 1.0 ± 1.3               | 2.9 ± 0.8               |
|                  | n.s                  | n.s              | n.s                     | n.s                     |

Table 3: Comparison between GTLI and BWSTT in post-training and 1 month after post-training.

Data are shown as number and mean ± SD. GTLI: Gait Training Using a Footpad-type Locomotion Interface, BW STT: Body Weight Supported Threadmill Training, TUG: Timed up & Go test, n.s: not significant

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