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# Effects of treadmill training with real optic flow scene on balance and balance self-efficacy in individuals following stroke: a pilot randomized controlled trial

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**Objective:** The objective of this study is to investigate the effect of treadmill training with real optic flow scene on functional recovery of balance and balance self-efficacy in stroke patients.
**Design:** Single blind, Randomized controlled trial.
**Methods:** Nine patients following stroke were divided randomly into the treadmill with optic flow group (n=3), treadmill with virtual reality group (n=3), and control group (n=3). Subjects in the treadmill with optic flow group wore a head-mounted display in order to receive a speed modulated real optic flow scene during treadmill training for 30 minutes, while those in the treadmill with virtual reality group and control group received treadmill training with virtual reality and regular therapy for the same amount of time, five times per week for a period of three weeks. Timed up and go test (TUG) and activities-specific balance confidence scale (ABC scale) were evaluated before and after the intervention.
**Results:** TUG in the treadmill training with optic flow group showed significantly greater improvement, compared with the treadmill training with virtual reality group and control group ($p < 0.05$). Significantly greater improvement in the ABC scale was observed in the treadmill training with optic flow group and the tread mill training with virtual reality group, compared with the control group ($p < 0.05$).
**Conclusions:** Findings of this study demonstrate that treadmill training with real optic flow scene can be helpful in improving balance and balance self-efficacy of patients with chronic stroke and may be used as a practical adjunct to routine rehabilitation therapy.

**Key Words:** Balance, Optic flow, Stroke

## Introduction

Hemiparesis after a stroke results most frequently in neurologic deficit [1], and its subsequent abnormal balance can be a cause of problems in daily life of stroke patients, as well interruption of motor recovery [2]; in addition, hemiparesis is one of the factors that increases the risk of falling, a cause of high economic costs and social problems [3-6].

Due to impaired function of the cerebral nerve system that integrates visual and proprioceptive information, stroke patients become deficit in visuo-spatial perception [7] exhibiting disability in control of balance and gait speed [8]. In addition, in order to maintain dynamic balance, it is necessary for visual information to play a major role [9], and for visual task and visual control, like optic flow, to improve balance by contributing to postural stability [10].

A few studies on the effect of training on balance using optic flow have recently been reported. In a study of treadmill training for four weeks using modulation of optic flow speed, targeting chronic stroke patients, Kang *et al*. [11] re-

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ported that training using modulation of optic flow speed corresponding to visual control and visual task resulted in improvement of dynamic balance. In addition, in a study of patients with Parkinson's disease who participated in a six-week training program involving application of optic flow, Almeida *et al*. [12] reported that providing patients with visual information, such as optic flow, resulted in improvement of their dynamic balance.

Further, the visual scene produced by directly shooting patients' in real life increases therapeutic effects by removing differences between virtual life and real life [13]. However, previous studies, mostly using virtual reality, have failed to overcome the difference between real and virtual, and, even in the application of modulation of optic flow speed, the setting of the optic flow speed and duration, which increases the gait speed of stroke patients, took on an ambiguous aspect.

Accordingly, our study will provide suggestions regarding the most effective training method for use in establishment of a rehab program for future stroke patients by direct application of a shot of a real life optic scene using a camcorder and program with focus on fast optic flow speed in training, and comparing the difference in changes of dynamic balance and balance self-efficacy between virtual reality training and conventional therapy.

## Methods

### Subjects

This study employed a randomized controlled pilot design. Nine persons with chronic hemiparetic stroke were recruited from B Hospital using a leaflet explaining the study information. The patients were randomly segregated into three groups: the treadmill with optic flow group (three patients), the treadmill with virtual reality control group (three patients), and the control group (three patients). The inclusion criteria for participation in this study were as follows: 1) hemiparetic stroke patients six months after diagnosis, 2) patients who were able to walk on their own for more than 15 minutes, 3) no auditory or visual deficits, 4) no orthopaedic or cardiovascular conditions that may interfere with the study, 5) no cognitive impairment ($>$24 in Mini-Mental State Examination) [11,14]. All subjects signed an informed consent form prior to participation in the study.

### Procedures

Subjects were randomly allocated to the treadmill with optic flow group or treadmill with virtual reality group or the control group. Each subject was given an envelope containing three cards and was instructed to blindly draw one card on each occasion. This study was conducted in a double-blinded manner: the person undertaking the assessment and data analysis was unaware of the grouping of each patient and the subjects and their therapist were unaware of the grouping of each patient.

Subjects in all of the groups participated in stretching added range of motion exercises for three weeks, five times per week, for one hour each day, according to the routine schedule of the rehabilitation unit. In addition, subjects in the treadmill with optic flow group and the treadmill with virtual reality group participated in exercises for three weeks, five times per week, for 30 minutes each day.

To ensure the safety of all patients during training, a physical therapist followed the patients while they were undergoing walking training and subjects who employed a treadmill wore a suspension device for safety purposes. Outcomes were measured before and after the three-week training period.

### Interventions

A system of treadmill training with real optic flow scene and treadmill training with virtual reality is shown in Figure 1.

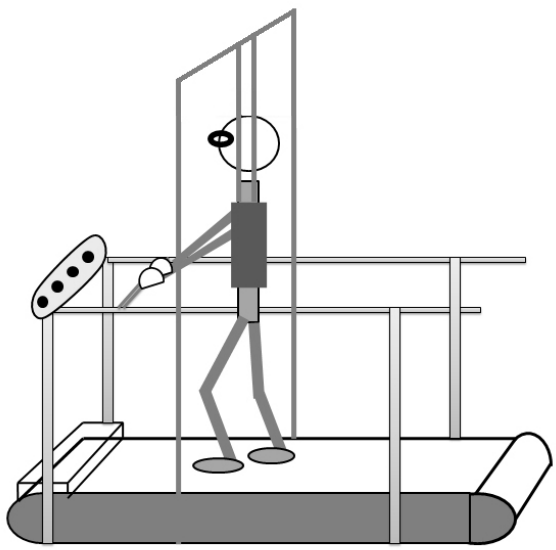

**Figure 1.** A system of training in both groups.

### *Treadmill training with real optic flow scene*

In the treadmill with optic flow group, the speed of optic flow applied to each patient could be manipulated, and the treadmill with real optic flow scene is a programme that reproduces the scene of walking in a real park. Video of the scene of walking in a real park was taken by a digital camcorder (HXR-NX70N, Sony, Tokyo, Japan). The treadmill with the real optic flow programme used computer hardware for the output, and was adapted to the subjects using a head-mounted device (MSP-209, Kowon Technology, Seoul, Korea). Prior to application of the optic flow speed, the gait speed of each subject was evaluated by performance of a 10-m gait test, and was re-tested every day. Based on studies reported by Lamontagne *et al*. [14], stable and inconsistent optic flow was determined and modified consists of the fast optic flow speed, and was applied in six sections: 0.5, 1.0, 1.5, 2.0, and 1.5, and 1.0 times the gait speed of each patient, with a training period of 1, 1, 2, 8, 2, and 1 minute for each section.

This study was performed two times for 15 minutes, and a set interval of five minutes was taken for the resting time. Patients wore earphones to adapt to the head-mounted device for five minutes before conduct of the experiment and for auditory control [11]. Treadmill (S25T, STEX, Seoul, Korea) training measured the 10-m gait speed of the patients, and execution of treadmill training was based on the measured stable gait speed. Once the patient was able to walk with stability for more than 20 seconds, the treadmill speed was increased by 0.1 km/h each time [15,16].

### *Treadmill training with virtual reality*

The virtual reality programme used the same scene as that used in the treadmill with optic flow group. The treadmill with the virtual reality programme used computer hardware for the output, and was adapted to the subjects using a head-mounted device (MSP-209). This study was performed two times for 15 minutes, and a set interval of five minutes was taken for the resting time. Patients wore earphones to adapt to the head-mounted device for five minutes before conduct of the experiment and for auditory control. Treadmill (Sky Life 5300, Iljin Sports, Seoul, Korea) training measured the 10-m gait speed of the patients, and execution of treadmill training was based on the measured stable gait speed. Once the patient was able to walk with stability for more than 20 seconds, the treadmill speed was increased by 0.1 km/h each time [15,16].

### Outcome measures

In this study, timed up and go test (TUG) and activities-specific balance confidence scale (ABC scale) were used in assessment of the balance and balance self-efficacy of the subjects.

TUG was performed for evaluation of dynamic balance. Each patient was asked to stand up, walk at a comfortable speed to the marked point, which was three meters away from a standard armchair, walking 3 m forward, turning 1808, returning, and sitting down again. The total time during this process was measured three times using a stopwatch, and the mean value was recorded. The intra-rater (r=0.99) and inter-rater (r=0.98) reliabilities demonstrated high reliability [17].

ABC scale test is a self-report questionnaire that asks individuals to rate their levels of confidence in performance of 16 ambulatory activities on a numerical rating scale ranging from 0 (no confidence) to 100 (complete confidence). The Korean version of the ABC was used in this study. The value is determined by dividing the total score by 16 and multiplying by 100, and the unit is %. The high test-retest (ICC=0.85) reliability has been demonstrated [18].

### Data analysis

The SPSS ver. 12.0 program (SPSS Inc., Chicago, IL, USA) was used for data analysis. Kruskal-Wallis was used to compare the change in scores of pre-and post treatment between each group, and post-hoc testing was performed using the Bonferroni test. Wilcoxon signed rank test was used to compare differences in value between the pre and post test. The significance level was set to $p < 0.05$.

## Results

A summary of the demographic data of the subjects is shown in Table 1.

The difference of dynamic balance and balance confidence after the training are shown in Table 2. The change value of TUG in the treadmill training with optic flow group (mean changeable score, 3.61±1.39) was significantly higher than that of the treadmill training with virtual reality group (mean changeable score, 2.01±0.94) and the control group (mean changeable score, 0.33±2.47) ($p < 0.05$, Figure 2). The change value of the ABC scale in the treadmill training with optic flow group (mean changeable score, 13.73±4.37)

**Table 1.** General characteristics of the subjects

| Variable | OF TRE | VR TRE | Control group |
|---|---|---|---|
| Gender | | | |
| Male | 2 | 2 | 1 |
| Female | 1 | 1 | 2 |
| Age (yr) | 58.33 (4.04) | 57.67 (10.60) | 68.33 (4.51) |
| Height | 167.00 (8.19) | 168.00 (6.25) | 163.67 (10.26) |
| Weight | 61.33 (8.96) | 65.33 (9.07) | 62.33 (9.23) |
| MMSE | 27.00 (2.00) | 27.33 (2.52) | 27.67 (0.58) |
| Post-stroke duration (mo) | 12.00 (3.00) | 12.33 (4.93) | 13.67 (2.08) |
| Etiology | | | |
| Ischemic | 2 | 2 | 1 |
| Hemorrhage | 1 | 1 | 2 |
| Paretic side | | | |
| Right | 2 | 2 | 3 |
| Left | 1 | 1 | 0 |

Values are presented as n or mean (SD).
OF TRE: treadmill training with optic flow group, VR TRE: treadmill training with virtual reality group, MMSE: Mini-Mental State Examination.

**Table 2.** Differences of dynamic balance and balance confidence between each group

| Variable | OF TRE | VR TRE | Control |
|---|---|---|---|
| TUG (s)[a-c] | | | |
| Pre | 20.96 (1.64) | 21.24 (3.78) | 24.13 (5.70) |
| Post | 16.42 (1.19) | 19.39 (3.86) | 23.75 (5.65) |
| Change values | 4.54 (0.44)* | 1.85 (0.24)* | 0.37 (0.05) |
| ABC scale (%)[a,c] | | | |
| Pre | 39.58 (2.18) | 44.75 (9.30) | 47.53 (2.58) |
| Post | 53.32 (6.52) | 53.14 (10.62) | 50.06 (2.78) |
| Change values | 13.73 (4.37)* | 8.39 (3.18)* | 2.52 (1.15) |

Values are presented as mean (SD).
OF TRE: treadmill training with optic flow group, VR TRE: treadmill training with virtual reality group, TUG: Timed Up and Go Test, ABC scale: Activities-specific Balance Confidence scale.
*Statistically significant difference between pre and post test ($p<0.05$). [a]Statistically significant difference between the treadmill training with optic flow group and the control group ($p<0.05$). [b]Statistically significant difference between the treadmill training with optic flow group and the treadmill training with virtual reality group ($p<0.05$). [c]Statistically significant difference between the treadmill training with virtual reality group and the control group ($p<0.05$).

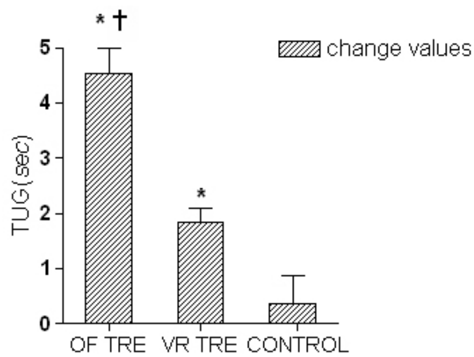


**Figure 2.** Changes between pre- and post-test of timed up and go test (TUG). OF TRE: treadmill training with optic flow group, VR TRE: treadmill training with virtual reality group. *Statistically significant difference compared to control group ($p<0.05$). †Statistically significant difference compared to treadmill training with virtual reality group ($p<0.05$).

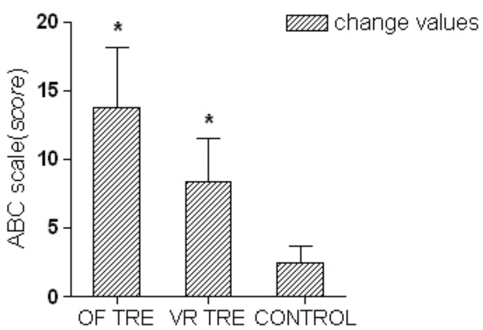


**Figure 3.** Changes between pre- and post-test of activities-specific balance confidence scale (ABC scale). OF TRE: treadmill training with optic flow group, VR TRE: treadmill training with virtual reality group. *Statistically significant difference compared to control group ($p<0.05$).

and the treadmill training with virtual reality group (mean changeable score, 8.39±3.18) was significantly higher than that of the control group (mean changeable score, 2.52±1.15) ($p<0.05$, Figure 3).

In addition, in the treadmill training with optic flow group and the treadmill training with virtual reality group, the value of the post test with TUG showed a significant decrease, compared to the value of the pre test ($p<0.05$). In the treadmill training with optic flow group and the treadmill training with virtual reality group, the value of the post test with the ABC scale showed a significant decrease, compared to the value of the pre test ($p < 0.05$).

## Discussion

This study was conducted in order to investigate the effect of treadmill training with optic flow on balance function and balance confidence in patients with chronic stroke. After three weeks of treadmill training with optic flow, subjects in the experimental group showed greater improvement of their balance function and balance self-efficacy, compared with those in the treadmill training with virtual reality group and the control group.

Balance, which is defined as the ability to maintain stability [19], is divided into static balance and dynamic balance; dynamic balance is the ability to maintain the posture when the base of support is in movement, or there is a stimulation from outside or during active movement [20], and it is important for functional activities, and is also a major purpose of rehabilitation [21]. In addition, in a psychological aspect, balance self-efficacy, is the most important factor in improving this balance, and dynamic balance and balance self-efficacy have significant interconnectivity [22,23].

Treadmill training, which affects motor relearning through creation of a functional link through formation of remapping of the sensory cortex and motor cortex after a stroke, is a task-oriented repeated training [24-26]. In addition, this treatment has an influence on balance by increasing muscular strength and improving symmetry in lower limbs [27,28]. In a study of speed-dependent treadmill training targeting patients with sub-acute stroke, Lau *et al*. [29] reported that treadmill training was effective in improvement of balance, and Matjacić [30] reported that treadmill training applied to a patient with an incomplete C5 level spinal cord injury also resulted in improvement of dynamic balance.

In recent active research on training with optic flow, it was found that a visual program using a real life scene drew responses from subjects through the interaction between computer hardware and software, resulting in an increase in functional activities by enhancing their interest and rate of participation in therapy [31], and has also been reported to have an influence on brain reorganization [32]. Brain reorganization through training with a visual program plays an important role in increasing neuro-plasticity of stroke patients while having an effect on balance [30,33] in accordance with the improvement in locomotion and symmetry in lower limbs by serving in the functional recovery of the affected side in lower limbs through the increase in contralateral brain activation of the brain damaged side [33].

In addition, modulation of optic flow produces incongruity of visual and proprioceptive information in lower extremity, and improves gait velocity with the motion of lower extremity changing according to modulation of optic flow speed [14,34]. Such an increase in gait velocity has a positive influence on dynamic balance [30], finally resulting in improvement of dynamic balance [11]. In addition, modulation of optic flow also has an influence on balance by revising somatosensory feedback in lower extremity and integrated information through the interaction between sensory cues [35]. Lee and Lishman [36] reported that subjects become confused between somatosensory information and visual information by the change of visual information, and improve their balance function by changing postures according to the input of visual information. Varraine *et al*. [35] reported on a study of the effects of the change in optic flow speed, cycle, and frequency on human gait; they found that it was possible to have an influence on balance function by integrating somatosensory information into the lower limb through the interaction between sensory cues, and changing locomotion. Kang *et al*. [11] reported that treadmill training using modulation of optic flow speed was significantly effective in improvement of dynamic balance and the somatosensory change through visual input was also found to change the balance function.

Balance self-efficacy has a close relationship with mobility, like gait ability [18], and it is improved by factors that promote functional mobility, such as the effects of self motor learning through sensory feedback, increase in neuroplasticity, and support of psychological stability [16]. Therefore, the effects of balance self-efficacy might also be improved through improvement in stroke patients' balance, gait, and muscle strength through treadmill training using modulation of optic flow speed, and its subsequent improvement in functional walking capacity.

Eventually, our study found that treadmill training using modulation of optic flow speed has a significant effect on the balance and balance self-efficacy of patients with hemiparetic stroke, and it might be possible to use this study result as an effective method for rehabilitation of future stroke patients with fall-related fear.

One limitation of this study is that, due to a small number of subjects, generalization of the results is difficult; and proper comparison of the difference between real optic flow scene and virtual reality scene could not be made because this study applied the real optic flow scene to the treadmill with optic flow group and treadmill with the virtual reality group on a similar basis. Accordingly, in future studies, it will be necessary to confirm the difference in effects of training according to the difference between the two scenes by implementation of treadmill training, which applies a virtual reality scene and real life optic flow scene to a large number of subjects differently.

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