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# Virtual dual-task treadmill training using video recording for gait of chronic stroke survivors: a randomized controlled trial

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**Abstract.** [Purpose] The aim of this study was to examine the effects of virtual dual-task treadmill training using a real-world video recording of the gait of individuals with chronic stroke. [Subjects] Forty chronic stroke survivors were randomly divided into two groups of 20 subjects each. [Methods] The experimental group performed virtual dual-task treadmill training using a video recording for 30 minutes per session, three times a week for 4 weeks, whereas the control group performed only treadmill training for 30 minutes per session, three times a week for 4 weeks. A video recording was performed in a large supermarket, and the subjects could walk at their favorable speed on a treadmill. The temporospatial gait variables were measured to examine the training effect. [Results] The experimental and control groups showed statistically significant improvements in the gait variables after training. The enhancement of gait ability was statistically better in the experimental group than in the control group. [Conclusion] Our findings suggest that virtual dual-task treadmill training using a video recording can improve the gait parameters of chronic stroke survivors.

**Key words:** Stroke, Gait, Video recording

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## INTRODUCTION

Individuals with stroke experience difficulty returning to their productive roles in society due to gait disturbances[1, 2)]. Neurological deficits resulting from the stroke lead to persistent functional impairment and physical problems caused by brain damage[3)]. The chief complaint is related to a change in gait ability[4)]. Increased gait ability can improve an individual's independence, participation in society, and quality of life as well as reduce the supporting costs of caregivers[5–7)]. Accordingly, gait training interventions are needed. Treadmill training is a useful exercise for mobility recovery, cardiovascular fitness, and whole-body metabolism[3)].

Various tasks are performed in daily life[8)]. Some tasks are required to perform a cognitive task while walking for community ambulation[5)]. In particular, high cognitive function is needed to complete these motor tasks[9, 10)]. When stroke patients perform dual tasks, their gait patterns, such as reductions in gait speed, are changed[11, 12)]. These gait changes result in difficult time-critical tasks, such as crossing the street safely in the community[5, 13)]. Therefore, the ability to perform dual tasks can be a helpful factor in returning to the community[5, 8)].

Cognitive-motor interference (CMI) is generated by the intense concentration when cognitive and motor tasks are simultaneously performed[11, 14)]. CMI changes by age group and is further increased in stroke patients[11)]. A cognitive task such as language or calculation may be more challenging for an individual with a lower education level[15)]. The increased CMI in stroke patients is caused by cognitive motor function damage. The dual task-related increase in CMI is significantly correlated with activities of daily living in stroke patients[16)]. To reduce CMI, automatization should be improved through repetitive gait training, whereas the coordination ability of dual tasks should be improved through task-oriented training[5, 17)].

Previous research on virtual reality training was performed improve gait ability[6, 9)]. Using virtual reality technology, it is easy to control the difficulty level and determine the interest and motives through visual, auditory, and tactile feedback, which provides individuals with experience and active learning[18)]. Movement re-education from various stimuli can help improve gait ability[19)]. The development of computers has resulted in three dimensional virtual real-

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ity tools. Virtual reality makes it possible to create realistic environment the enable safer and more efficient indoor training[9]. The outdoor environment is a difficult setting in which to develop community mobility in stroke patients[6].

On the other hand, the need for special hardware or software is a weakness of existing virtual reality training system. In addition, although the actual environment can be represented, it does not resemble real-life. To complement such limitations, virtual training using a video recording is needed.

The aim of this study was to develop virtual reality images that more closely resemble real life by recording a place that can be commonly observed in daily life. The effect of virtual dual-task treadmill training was examined through video recording of the gait of stroke.

## SUBJECTS AND METHODS

The subjects were recruited from rehabilitation hospital. The inclusion criteria were hemiplegic subjects who had experienced a middle cerebral lesion and stroke at least 6 months earlier to exclude natural restoration, subjects who scored greater than 24 points on the Mini-Mental State Examination-Korea, and could understand and follow the intervention and walk 10 m independently.

Patients with vestibular system disease, cerebellar disease, visual disability, visual defect, sensory aphasia, auditory disability, auditory defect, neurologic diseases, or orthopedic diseases that could have affected the study were excluded.

After explaining the study objective and procedures, only those subjects who voluntarily provided written consent were allowed to participate.

This study was a pilot randomized single-blind controlled trial. To minimize bias, the selected participants were randomly allocated into the experimental and control groups according to the treatment condition using Random Allocation Software (ver. 2.0)[20]. Subjects in the experimental and control groups received traditional physical therapy for 1 hour, five times a week for 4 weeks. The experimental group performed virtual dual-task treadmill training using a video recording for 30 minutes per session, three times a week for 4 weeks, whereas the control group performed only treadmill training for 30 minutes per session, three times a week for 4 weeks (Fig. 1). The study was approved by the Sahmyook University Institutional Review Board.

Virtual dual-task treadmill training was performed in a separate space. In contrast to the existing computer program, the first-person scene, in which a cart is pushed in a major supermarket, was recorded using a camcorder (VIXIA HF-R20, Canon Korea, KOREA, 2010). The moving speed of cart was maintained at 100 cm/s while the video was recording. The experimental group walked on the treadmill (STEX 620T, Taeha Mechatronics, KOREA, 2009) while looking at the recorded scene. The 100 inch screen was placed closely enough to the subject to cover the visual field. The gait speed at which the participants could walk comfortably was selected. To match the flow of the surrounding objects on the screen with each individual's gait speed, the speed ratio suitable for each gait speed was set up in advance (Gom Player

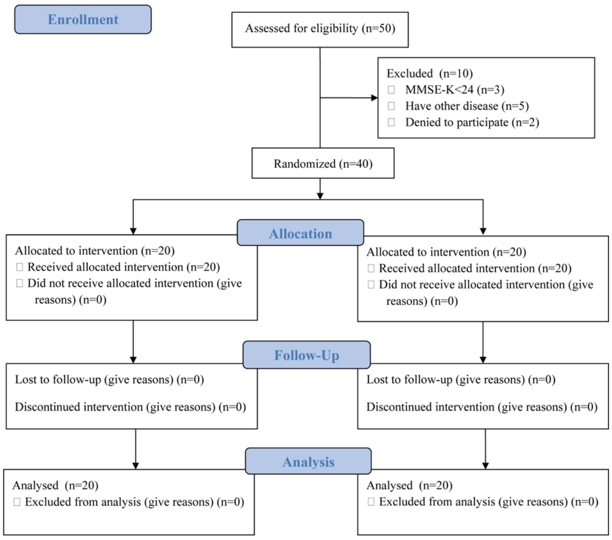


**Fig. 1.** Experimental flow diagram according to CONSORT

v2.1.46.5131). In every session, the therapist checked the selected gait speed. Since the environment was set up to be similar to reality through recorded sounds, the subjects were trained to walk and push the handle as though they were pushing a real cart. Before starting, all of the subjects were asked to remember five items and press a buzzer after finding those items in the recorded scene. A new set of items was located each time and included product such as detergents, certain fruits like bananas, apples, pineapples, specific soft drinks and snacks, bread, and a dehumidifying agent. When an object presented on the screen was passed, even if the subject pressed the buzzer, it was excluded from the count. The subjects showed a reaction to four or more items each time.

The control group simply walked on a treadmill at a preferable speed for 30 minutes[21]. A therapist always accompanied the subjects during walk to prevent falls.

To examine an individual's basic capacity for the inclusion criteria, a gait ability test was administered before training.

An electronic gait carpet containing a total of 2,304 sensors (1 cm diameter) placed vertically every 1.27 cm was used. The collected data related to the temporospatial variables were processed using GaitRite GOLD version 3.2b software (CIR System Inc, USA, 2007). To reduce participant-related acceleration and deceleration errors, the GaitRite was placed 1 m ahead of the departure point and 1 m behind the finishing point. The mean values of three measurements were used.

After training, the gait ability was tested again to examine the total training effect. The mean and standard deviation were calculated using SPSS ver. 18.0. The data normality was assessed using the Shapiro-Wilk test prior to training. Descriptive statistics were used to analyze the participants' general characteristics, while an independent t-test was performed to examine the differences between the two groups. A paired t-test was performed to compare the pre- and post virtual dual-task treadmill training data using a video record-

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

| | Experimental group (n=20) | Control group (n=20) |
|---|---|---|
| Age (years) | 51.0 ± 13.5 | 48.1 ± 7.5 |
| Body weight (kg) | 70.6 ± 15.7 | 65.1 ± 6.4 |
| Height (cm) | 169.4 ± 7.5 | 166.2 ± 7.0 |
| Gender (male/female) | 12/8 | 14/6 |
| Affected type (infarction/hemorrhage) | 13/7 | 12/8 |
| Paretic side (right/left) | 12/8 | 13/7 |
| MMSE-K (score) | 27.3 ± 3.2 | 27.5 ± 3.6 |

MMSE-K: Mini-Mental State Examination-Korea; NS: not significant. Values are presented mean ± SD

ing of each group. The level of statistical significance (α) was set at 0.05.

## RESULTS

Of the 50 subjects initially recruited, we included the 40 who met the inclusion criteria. Twenty subjects were allocated randomly into the experimental group, whereas the other 20 were allocated to the control group. There were no significant differences between the two groups (Table 1).

The gait speed, cadence, step length time, stride length time, step length, and stride length on the paretic side were significantly greater in the experimental group ($p<0.05$). Although the control group also showed improvements, there were significant differences between the two groups after training ($p<0.05$).

The mean gait speed of the experimental group increased from 0.80 m/s before training to 1.04 m/s after training ($p<0.05$). The cadence also increased from 88.48 steps/min before training to 106.23 steps/min after training ($p<0.05$). The step length time on the paralysis side decreased from 0.64 seconds before training to 0.52 seconds after training ($p<0.05$), while the stride length time on the paralysis side also decreased from 1.26 seconds before training to 1.02 seconds after training ($p<0.05$) (Table 2).

In the experimental group, the step length on the paralysis side increased from 53.52 cm before training to 58.52 cm after training ($p<0.05$), and the stride length on the paralysis side increased significantly from 100.63 cm before training to 110.25 cm after training ($p<0.05$) (Table 3).

## DISCUSSION

This study showed that dual-task training was useful for improving the gait ability of stroke survivors in a virtual reality environment using a video recording. Our findings suggest that the temporospatial parameters of gait were improved because the virtual dual-task training reduced the CMI.

Significant improvement in gait speed, cadence, and functional ambulation by treadmill training was previously demonstrated through advanced research[3, 22]. This study also revealed significant improvement in the gait variables in both groups ($p<0.05$). Therefore, we conclude that treadmill training effectively improves gait ability. On the other hand, the initial rehabilitation goal of increasing gait speed was not sufficient to return to the community[8, 23]. Unless both cognitive and physical functions can be recovered in patients with a damaged central nervous system, their movement and mobility in daily life will be limited, including those in the community[24]. Therefore, performing dual-tasks during gait in an actual environment is essential to their return to society.

Elderly people or patients whose nervous systems are damaged need to pay more attention to their gait than healthy young people[8]. Because of aging-induced physical and neurological changes[25] after stroke, patient's reaction time can be delayed and attention capacity can be reduced due to neurological impairments[24]. An increased reaction time indicates more challenging postural control, and the attention demands of gait can influence one's safety in terms of community mobility[15].

Human central processing is affected by the stimulus-response compatibility and psychological refractory period[26]. In particular, the reaction time was increased when participants performed a dual task due to a central bottleneck paradigm. The main cause of the psychological refractory period is the central bottleneck paradigm, but this can be eliminated by practice. Therefore, automatization through repeated practice is essential for reducing dual-task interference[27]. In this study, the participants were asked to finding items before training and perform cognitive tasks that require continuous attention while walking. Such tasks can be accelerated by automatization.

Automatization of the control group was improved due to the repetition of treadmill walking, whereas the proper allocation ability of coordination and attention was improved in the experimental group by virtual dual-task training, which led to the decreased CMI. CMI is a phenomenon that results in the deterioration in many aspects of gait ability, such as slower gait speeds, reduced cadence, and shorter stride length[28]. In the experimental group, the perturbation that occurred when the buzzer was pressed was consistently controlled, and walking at the same rate in the situation was thought to have resulted in improved gait ability. Thus, the automatization of the experimental group led to decreased CMI, which is linked to increased gait ability.

Visual feedback in the virtual reality environment motivates the participants to actively participate in the training[29]. Improvements in concentration as well as postural stability contribute to a normal gait pattern[30]. Through this, the gait

**Table 2.** Temporal gait parameters for dual-task and single-task conditions

| | Gait speed (m/s) | | | Cadence (step/min) | | | Paretic step time (s) | | | Paretic stride time (s) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pre | post | changes | pre | post | changes | pre | post | changes | pre | post | changes |
| Experimental group (n=20) | 0.8 ± 0.3 | 1.0 ± 0.3* | 0.2 ± 0.2† | 88.5 ± 25.7 | 106.2 ± 27.2* | 17.9 ± 9.0† | 0.6 ± 0.1 | 0.5 ± 0.2* | 0.1 ± 0.1† | 1.3 ± 0.3 | 1.0 ± 0.3* | 0.3 ± 0.3† |
| Control group (n=20) | 0.8 ± 0.4 | 0.9 ± 0.3* | 0.1 ± 0.1 | 89.3 ± 23.6 | 100.0 ± 17.7* | 10.7 ± 11.5 | 0.6 ± 0.1 | 0.6 ± 0.1* | 0.0 ± 0.1 | 1.2 ± 0.2 | 1.2 ± 0.2* | 0.1 ± 0.2 |

Values are presented mean ± SD.
*p <0.05: significant difference between baseline and after the intervention
†p <0.05: significant difference between both groups

**Table 3.** Spatial gait parameters for dual-task and single-task conditions

| | Step length (cm) | | | Stride length (cm) | | |
|---|---|---|---|---|---|---|
| | pre | post | changes | pre | post | changes |
| Experimental group (n=20) | 53.5 ± 7.8 | 58.5 ± 7.7* | 5.0 ± 2.4† | 55.6 ± 10.3 | 57.4 ± 10.2* | 1.8 ± 3.3 |
| Control group (n=20) | 100.6 ± 15.3 | 110.3 ± 15.3* | 9.6 ± 6.7† | 104.8 ± 16.8 | 107.2 ± 17.9* | 2.4 ± 4.1 |

Values are presented mean ± SD.
*p <0.05: significant difference between baseline and after the intervention
†p <0.05: significant difference between both groups

ability of stroke patients was improved.

Based on a representation of virtual reality using a video recording, it is possible to secure the strengths of virtual reality and select images that represent an actual environment. Even without special software, it is possible to clinically harness this technology. The task difficulty can be controlled in phases by providing real visual-audio feedback during task performance.

On the other hand, this study was limited in that it was conducted only on stroke patients who could walk independently. Therefore, these results are only applicable to patients who can walk independently despite severe disability after stroke. In addition, the task was performed only in a major supermarket. Therefore, it would be necessary to provide participants with a chance to be exposed to additional environments using video recordings.

The results of this study are clinically and potentially important. In stroke patients, multiple factors should be considered. Dual tasks should be considered when attempting to achieve qualitative gait improvements as opposed to quantitative improvements in the rehabilitation process. Virtual reality using video recordings can be used to help patients return to the community by attracting their interest. Nevertheless, additional research into the effects of this strategy on quality of life is needed.

Similarly, virtual dual-task treadmill training using a video recording has strengths related to both dual-tasks and virtual reality. The intervention of virtual reality provided stroke survivors with motivation and emotional stability, and their neuroplasticity increased through repetitive training of their damaged lower extremities, resulting in improved gait ability. Therefore, the control group probably showed more efficient improvements in gait ability.

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