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Effect of treadmill training based real-world video recording on balance and gait in chronic stroke patients: A randomized controlled trial

Ki Hun Cho [a,b], Wan Hee Lee [a,*]

[a] Department of Physical Therapy, Sahmyook University, Republic of Korea
[b] Department of Physical Therapy, Seoul Bukbu Hospital, Republic of Korea

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ABSTRACT

Objective: The purpose of this study was to determine the role of treadmill training based real-world video recording (TRWVR) for balance and gait ability in chronic stroke patients.
Design: Thirty chronic stroke patients were randomly assigned to either the TRWVR group ($n = 15$) or the control group ($n = 15$). Both groups participated in a standard rehabilitation program; in addition, the TRWVR group participated in TRWVR for 30 min per day, three times per week, for 6 weeks, and the control group participated in treadmill walking training for 30 min per day, three times per week, for 6 weeks. Balance ability was measured using the Berg Balance Scale (BBS), Timed Up and Go test (TUG) and the postural sway by force platform system. Gait performance was measured using a pressure sensitive walkway.
Results: Significant differences in the time factor for dynamic balance and gait ($P < 0.05$) were observed in the TRWVR and control group, with the exception of static balance. For the group × time interaction, significant improvements in dynamic balance and gait ($P < 0.05$). In the correlation coefficient, no significant correlation was observed between changes in postural sway and other dependent variables.
Conclusions: Findings of this study demonstrated that the real-world video recording has an effect on dynamic balance and gait in chronic stroke patients when added to treadmill walking.
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1. Introduction

Among various approaches to achieve independent walking of stroke patients, treadmill training led to improvement of overground walking and endurance in both subacute stages [1], and chronic stroke patients [2] by providing increased intensity with a task repetitive approach to the concept of motor learning. However, to date, researches on treadmill based locomotor training programs for stroke patients has been conducted in laboratory or clinic and hospital settings [1,2], and the real-world suitability of the findings for community ambulation can only be estimated [3,4]. In addition, some research has identified difficulties in achievement of community ambulation, due to environmental factors, which requires high level motor skills, such as an ability to adapt to unexpected disturbances, external perturbations, and environmental conditions [5]. The role of environmental factors in independent walking has been the focus of recent research, with evidence indicating that cortical input demands vary with the environment in which it is performed [6].

Virtual reality (VR) has recently been used to provide stroke patients with opportunities for interaction with environments similar to the real-world [7]. VR facilitates the input and output of information, and when used in combination with other interventions, can provide the necessary tools for design of a variety of environments and complex tasks [8]. In particular, VR combined with use of a treadmill training system can provide motivation and achievements to users by allowing interaction with the virtual environment [9], and the user can receive real time feedback during treadmill walking [10,11]. Yang et al. [7] reported that VR treadmill system using a screen projected image was effective in improvement of balance in the medio-lateral direction, sit to stand transfer, and involvement of the paretic limb in level walking in stroke patients. Walker et al. [11] demonstrated that use of a VR system combined with body weight support treadmill training is feasible for improvement of gait and balance in stroke patients. In addition, more recent evidence on virtual walking training using a real-world video recording suggested that the VR based real-world video recording may be a valid approach to enhancement of gait performance in stroke patients [12]. Although these studies have

* Corresponding author at: 26-21, Gongneung2-dong, Nowon-gu, Seoul 139-742, Republic of Korea. Tel.: +82 2 3399 1633; fax: +82 2 3399 1639.
E-mail address: whlee@syu.ac.kr (W.H. Lee).

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provided evidence of the positive effects of treadmill training combined with VR on balance and gait ability in stroke patients, due to small sample size, lack of homogeneity of subjects, and lack of a comparison group with random assignment of conditions, it is difficult to generalize their results. In addition, previous studies suggested that further study using larger groups of patients is needed for investigation of the effects of intervention.

Hence, the purpose of this study was to demonstrate the role of treadmill training based real-world video recording (TBRVR) for improvement of balance and gait in chronic stroke patients. Our hypothesis was that the TBRVR would be more effective than treadmill walking training alone for improvement of balance and gait in chronic stroke patients.

2. Subjects and methods

2.1. Participants

Thirty-seven chronic stroke patients were recruited for this study. Participants were screened according to the following inclusion and exclusion criteria. The inclusion criteria were hemiparesis resulting from a single stroke for more than 6 months; ability to walk with and without use of an assistive device for 10 m; able to understand and follow simple verbal instructions (Korean version of Mini-Mental State Examination score >24) and no severe heart disease or uncontrolled hypertension. Exclusion criteria for the study were orthopedic and other gait influencing diseases such as arthrosis or total hip joint replacement [1] and participation in other studies or rehabilitation programs. Five of the 37 subjects were excluded because they met the exclusion criteria. We explained the objective and requirements of our study to all participants and all patients provided informed consent prior to participation. Ethical approval for the study was granted by the Sahmyook University institutional review board.

2.2. Procedure

Thirty-two participants were randomly assigned to either the TBRVR group or the treadmill training (TT) group. For randomization, sealed envelopes were prepared in advance and marked of the inside with O or X. Randomization was performed one hour prior to the start of the pretest, by a physical therapist who was not involved in the assessment or treatment of the subjects. Participants were evaluated two times, one-week before and one day after the six-week intervention phase. All assessments were performed by three physical therapists who were blinded to the treatment allocations. One subject in each group withdrew from the training program within the first two and three weeks of the study period, for the following reasons: bladder infection with fever and discharge. Thus, data from 30 patients (TBRVR group: $n = 15$, mean age: 65.86 years, post stroke duration: 414 days; TT group: $n = 15$, mean age: 63.53 years, post stroke duration: 460 days) were analyzed. G-Power 3.13 software was used to calculate sample size. The power and the alpha level were set as 0.8 and 0.05, respectively. And, the effect size (Cohen d) was set at 1.16. According to a priori analysis, at least 13 subjects were required in each group.

All patients enrolled in this study participated in standard rehabilitation programs (five times per week, for 6 weeks) consisting of physical and occupational therapy and functional electrical stimulation (FES). Neurodevelopmental treatment and proprioceptive neuromuscular facilitation were performed during each session of physical therapy (30 min per day). Occupational therapy, functional exercise of the upper extremity for improvement of activities of daily living, was performed for 30 min per day. FES was applied to the lower extremity for 20 min per day. In addition, experimental group participated in TBRVR, and control group participated in treadmill walking training for 30 min per day, three times per week, for 6 weeks.

2.3. Treadmill training based real-world video recording (TBRVR)

The TBRVR included a combination of treadmill walking training (JT-4000, Saehan Medical, Gyeonggi-do, Korea) and a screen shot of real-world video recording produced using a video camera (Nex-5, Sony, Tokyo, Japan) and a steadicam camera stabilizing system (Flycam nano, PIS, Seoul, Korea). Real-world video recording, composed of six screen shots, was projected onto a 170 × 200 cm (width × length) screen in front of the treadmill (2 m) using a projector and a laptop. At the same time, auditory input, which recorded real-sound during real-world video recording, was provided using a 50 w (25 × 2) loud speaker. While walking on the treadmill, participants view a virtual environment using the real-world video recording, which depicts a sunny 400-m walking track, a rainy 400-m walking track, a 400-m walking track with obstacles, daytime walks in a community, nighttime walks in a community, and walking on trails. The progression of the real-world video recording protocol is shown in Fig. 1. While TBRVR, each subject was asked to lift head and look at the real-world video recording projected onto screen. The instructions during TBRVR were as follows: "Walk with your head up and look at the screen in front of you." The six screen shots were changed at intervals of one week during the training period. Each screen shot was played for 10 min, and repeated three times during the 30 min TBRVR session.

During all training sessions, participants wore a safety harness that did not support any body weight. In addition, emergency stop devices were installed for the participants' safety. Patients participated in 18 sessions of TBRVR over six weeks, with a total of 30 min of walking during each session. Rest breaks were allowed if requested, but were not included in the overall walking time. All participants walked on a motorized treadmill, starting at a self-selected comfortable walking speed. Self-selected comfortable walking speed was defined as treadmill walking speed when instructed to "walk at your normal comfortable speed" [13]. A self-selected comfortable walking speed on the treadmill was measured before the start of the intervention. The treadmill speed was increased by 5% during the subsequent training session if the subject was able to maintain the training speed while feeling safe for a period of 20 seconds [9]. Heart rate and blood pressure were monitored before and after each session in order to prevent any other signs of excessive fatigue. In the TT group, speed and duration of treadmill walking were controlled using the same method used in the TBRVR group, with the exception of the real-world video recording projection.

2.4. Instruments

Balance assessments were composed of static and dynamic balance ability. Static balance ability was measured with the postural sway using a force platform system (Good Balance system™, Metitur Ltd, Jyvaskyla, Finland) which is connected to a computer through a three-channel amplifier with an A/D converter (sampling frequency = 50 Hz). [14]. For measurement of postural sway, a subject stood on the force plate with legs spread at shoulder width, and then looked at a number on a monitor three times for 30 seconds. Three repeats of each measurement were performed and the average was used in the statistical analysis. A rest period of 3 min was provided between measurements.

The Berg Balance Scale (BBS) and the Timed Up and Go test (TUG) were used for measurement of dynamic balance ability. BBS is a valid and reliable instrument for measurement of both the

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