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Effects of game-based virtual reality on health-related quality of life in chronic stroke patients: A randomized, controlled study

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ABSTRACT

In the present study, we aimed to determine whether game-based virtual reality (VR) rehabilitation, combined with occupational therapy (OT), could improve health-related quality of life, depression, and upper extremity function. We recruited 35 patients with chronic hemiparetic stroke, and these participants were randomized into groups that underwent VR rehabilitation plus conventional OT, or the same amount of conventional OT alone, for 20 sessions over 4 weeks. Compared to baseline, the VR rehabilitation plus OT group exhibited significantly improved role limitation due to emotional problems ($p=0.047$). Compared to baseline, both groups also exhibited significantly improved depression ($p=0.017$) and upper extremity function ($p=0.001$), although the inter-group differences were not significant. However, a significant inter-group difference was observed for role limitation due to physical problems ($p=0.031$). Our results indicate that game-based VR rehabilitation has specific effects on health-related quality of life, depression, and upper extremity function among patients with chronic hemiparetic stroke.

1. Introduction

Stroke affects various aspects of human activity, participation, and life. Upper limb motor deficit is known to be the most common impairment in the acute phase of stroke (77.4% of all cases), and persists in approximately half of all chronic stroke survivors [1,2]. Furthermore, upper limb motor deficit affects the quality of life of these patients, and improving upper extremity function remains a major component of rehabilitation among stroke patients. Therefore, a variety of interventions have been developed for this purpose, and virtual reality (VR) has recently been described as a promising tool for rehabilitation. In this context, VR provides a computer-generated real-time simulation of an activity or environment, which promotes a virtual experience via interactions between the user and artificial environments. It has also been suggested that VR could provide high-intensity, repetitive, and task-specific training. Virtual reality was introduced as an assistive technology for neurorehabilitation approximately 25 years previously, and was introduced specifically for stroke rehabilitation in the early 2000s [3], where it is gaining popularity, despite inconsistent results. In their pragmatic clinical trial among 376 stroke patients, Turolla et al. [4] demonstrated that a combination of VR-based rehabilitation with conventional therapy provided greater improvements in upper limb motor function and capacity for activities of daily living, compared to the same amount of conventional therapy alone. In addition, the improvements in kinematic and clinical outcomes were superior in the VR group, compared to the group that received conventional therapy alone [5]. However, other studies have concluded that there were no significant differences when VR rehabilitation was combined with conventional interventions [6,7].

Non-immersive game systems have recently been adopted as VR for rehabilitation, and have become more popular with the advent of off-the-shelf commercial systems. For example, the Nintendo® Wii or Microsoft Kinect™ systems provide a motion-based control interface, which makes these systems applicable and suitable for rehabilitation that is focused on motor function. These systems are also relatively affordable, and are widely available in many non-hospital settings. Unfortunately, the therapeutic effect of VR gaming has not been consistent, and is known to vary according to the outcome measures and classification systems that are used [8,9]. Furthermore, the studied outcomes have been limited to motor-related factors, such as range of motion, strength, and body function, and do not consider the patient's quality of life.

Health-related quality of life (HRQOL) is defined as the quality of life that is affected by disease, and is a multidimensional measure that includes physical, social, and emotional health.

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Therefore, HRQOL measurements more accurately reflect the status of participants, compared to functional or impairment measures [10,11]. Although HRQOL is subjectively evaluated from the participant's perspective, it is known to be a powerful predictor of mortality and morbidity [12]. Furthermore, it is difficult to improve HRQOL in stroke survivors, which is often very poor [13]. Specific interventions include botulinum toxin type A injection or robot-assisted therapy, which have a significant effect on HRQOL; however, the effects of VR rehabilitation on HRQOL among stroke patients has not been determined [14]. Therefore, the objective of the present study was to determine whether HRQOL, depression, and upper extremity function could be improved using game-based VR rehabilitation plus conventional occupational therapy (OT), compared to the same amount of conventional OT alone.

2. Material and methods

2.1. Participants

Patients who were aged ≥ 18 years and had chronic hemiparetic upper limb dysfunction, secondary to a first-ever stroke, were prospectively recruited between January 2012 and March 2014 from one university hospital and one rehabilitation hospital. A total of 117 potential candidates were screened for eligibility, and all exhibited mild-to-moderate deficits of their paretic upper extremity at the time of enrolment. Eligibility was determined using Medical Research Council Scale scores of ≥ 2 (able to move the extremity with full range of motion, when gravity is eliminated) and ≤ 4 (able to complete the range of motion against gravity with moderate resistance) and a Brunnstom motor recovery stage for the proximal upper extremity of ≥ 2 (limb synergy develops out of flaccid paralysis, and spasticity appears, although not marked) and ≤ 5 (relative independence out of the limb synergies, and spasticity wanes) [15]. The exclusion criteria were severe cognitive impairment or aphasia (which impaired the participant's ability to follow instructions), pre-existing mental illness or arm impairment, difficulty in sitting for at least 30 min, and/or uncontrolled medical illness. All patients provided their written informed consent before participating in the study. The study was conducted in accordance with the Declaration of Helsinki, and its design was approved by the institutional review board of the National Rehabilitation Center and Hanyang University.

3. Methods

This prospective, randomized, single-blind, parallel-group study used a two-factorial repeated measures design to compare the changes in HRQOL, depression, and motor function due to VR+OT or OT alone, among participants with chronic stroke. The participants were randomly divided in a 1:1 ratio into two groups using a computer-generated randomization schedule. The OT group received 30 min of conventional OT, plus an additional 30 min of OT, for a total of 1 h of OT. The VR+OT group received 30 min of conventional OT, plus 30 min of game-based VR rehabilitation with the RehabMaster™ system (D-Gate, Seoul, Korea) (Fig. 1). The conventional OT was similar to standard OT, which includes range of motion and strengthening exercises for the affected limb, table-top activities, and training for activities of daily living. The additional 30 min of OT or VR rehabilitation was variably conducted by two trained occupational therapists who were exclusively dedicated to this study. The framework for the additional therapies was designed to promote the use of the affected limb and movement of the trunk, depending on the participant's functional status, and comprised various motions, such as reaching, catching, wrist flexion or extension, and grasping. The therapists adjusted the difficulty of the OT by controlling the target's placement or weight, or task speed. The interventions were performed 5 days per week for 4 weeks.

The RehabMaster™ is a game-based VR rehabilitation system, which uses the OpenNI™-compliant depth sensor, PrimeSense™ 3D awareness sensor, infrared projectors, and standard red–green–blue and infrared (IR) complementary metal–oxide semiconductor image sensors for VR rehabilitation. The infrared projectors emit thousands of IR beams towards an object, which subsequently reflects the beams back towards an infrared camera. The PrimeSense™ 3D awareness sensor is linked to a software development kit, which calculates the distance between each reflected infrared beam. After completing these distance calculations, a depth image

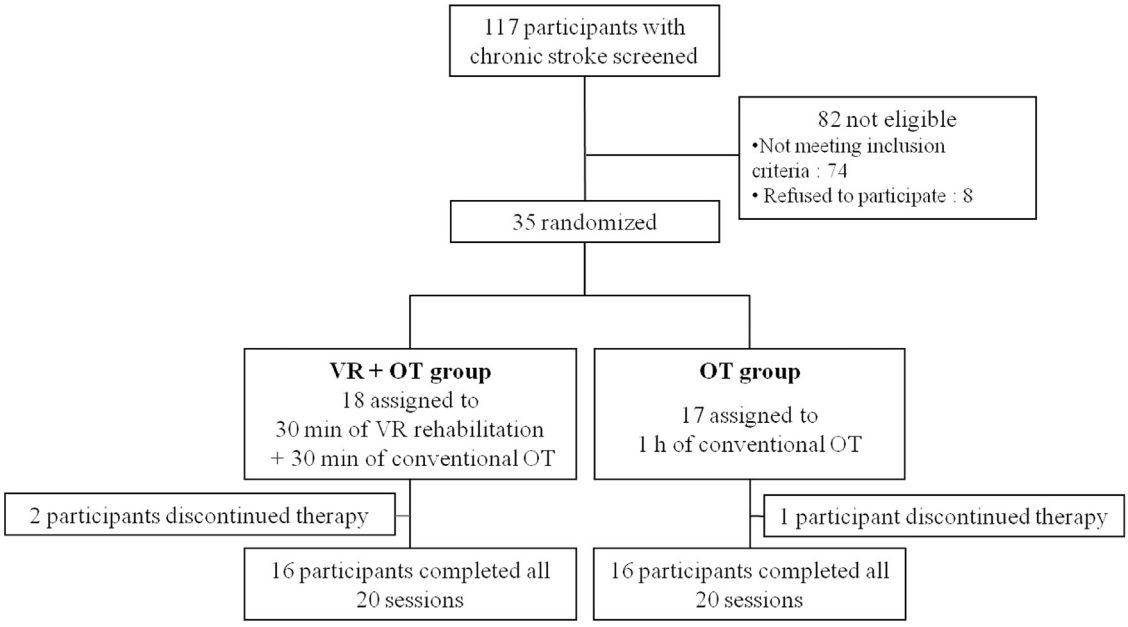

Fig. 1. Study flow chart. VR: virtual reality, OT: occupational therapy.