Effects of virtual reality training using Nintendo Wii and treadmill walking exercise on balance and walking for stroke patients

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Abstract. [Purpose] The purpose of this study is to investigate the effects of virtual reality training using Nintendo Wii on balance and walking for stroke patients. [Subjects and Methods] Forty stroke patients with stroke were randomly divided into two exercise program groups: virtual reality training (n=20) and treadmill (n=20). The subjects underwent their 40-minute exercise program three times a week for eight weeks. Their balance and walking were measured before and after the complete program. We measured the left/right weight-bearing and the anterior/posterior weight-bearing for balance, as well as stance phase, swing phase, and cadence for walking. [Results] For balance, both groups showed significant differences in the left/right and anterior/posterior weight-bearing, with significant post-program differences between the groups. For walking, there were significant differences in the stance phase, swing phase, and cadence of the virtual reality training group. [Conclusion] The results of this study suggest that virtual reality training providing visual feedback may enable stroke patients to directly adjust their incorrect weight center and shift visually. Virtual reality training may be appropriate for patients who need improved balance and walking ability by inducing their interest for them to perform planned exercises on a consistent basis.

Key words: Balance, Virtual reality training, Walking

INTRODUCTION

Many stroke patients with stroke have a balance problems while standing because they tend to put their weight on their non-paralyzed lower limb to increase swing of their upper body¹. Falling accidents due to such decline in balance ability is on the increase annually. Falling is caused by sudden paralysis, seizure or external pressure. Even when there is no injury from falling, frequent falling can sufficiently disrupt physical and social activities². Because deterioration of muscular strength and balance ability increases the risk of falling, it is significantly important to perform exercises to promote upper limb muscular strength and training for balance³. Regular exercise of walking and for muscular strength and balance may increase muscular strength and balance ability of patients⁴. Walking, in particular, is known to be a safe type of aerobic exercise for patients, having the merit that it can be performed gradually by considering appropriate intensity, frequency, period, and phases of exercise for abilities of each patient⁵. Recently efficiency of walking training using a treadmill has attracted more attention as when such training has been reported to have better effects than walking on even ground. Some researchers reported that walking on a treadmill is effective in improving balance and walking ability⁶, ⁷.

With recent developments of relevant computer programs, new methods of rehabilitation exercise are being introduced. Such exercises can increase interest and participation of patients in treatment and improve their significant functions by enabling them to perform various forms of tasks appropriate for goals of individual patients in virtual reality. Virtual reality
indicates a type of interactive simulation using computer hardware and software, in which users can have close-to-reality experiences\(^5\). Virtual reality training using visual feedback enables the participants to undergo the training while seeing their movements with their own eyes, a feature that helps them adjust their inaccurate body center caused by body image damage suffered by most stroke patients. In addition, training serves as a catalyst in active participation and performance of tasks by inducing interest and pleasure, providing immediately visual feedback on the result to enhance motor education ability\(^9\). Many recent researches of virtual reality games with higher accessibility reported that such games showed significant effects on voluntary control and coordination of children with cerebral palsy and increases in the motor ability of patients with Parkinson disease\(^10\). Those types of games were also effective on recovery of upper limb functions and induced significant improvement in balance and walking of stroke patients, showing that the games can be used as an effective method of intervention\(^11, 12\).

As a means of overcoming limitations of the existing intervention methods, virtual reality shows an availability it has to being applied in the rehabilitation of stroke patients. However, devices of virtual reality in previous studies are so large that they are difficult to be used in general social institutes or homes in terms of scale and cost. Furthermore, they are targeted to a small number of patients. In this context, the purpose of this study was to perform treadmill exercise and virtual reality training exercise using Nintendo Wii, a device that can be easily used without regard to place or facility, in order to investigate the effects on balance and walking of stroke patients.

**SUBJECTS AND METHODS**

Forty stroke patients participated in this study. All of the subjects were sufficiently explained of this study and voluntarily consented to their participation in the experiment. This study was approved by the research agency, and all participants provided written informed consent. Those who could perform communication, comply with instructions in this study, perform balancing and walking independently, had no pain limiting execution of exercise, and had no disability in sight, hearing, and the vestibular organs were selected to be the subjects of this study. The forty stroke patients were randomly divided into two exercise program groups with one group using virtual reality training (\(n=20\)) and another group using a walking exercise program using a treadmill (\(n=20\)). Age for the virtual reality group, the age was 62.2 ± 7.2 years old, the height was 162.8 ± 6.7 cm, the weight was 58.1 ± 5.4 kg, and the onset period was 30.4 ± 5.4 months. Age for the treadmill group, the age was 63.2 ± 5.4 years old, the height was 164.7 ± 7.5 cm, the weight was 60.2 ± 4.5 kg, and the onset period was 31.6 ± 7.4 months.

All subjects exercised for 40 minutes three times per week for eight weeks. The virtual reality group underwent training using the Wii-fit software by Nintendo, Japan. When playing the Nintento Wii, the participants used wireless controllers to interact with the avatars on the screen via the virtual reality motion detection system. The controllers were attached by acceleration detecting sensors responding to changes in direction and speed. Due to the detector being installed on the television, the screen showed the movements of the controller just as the player performed the movements\(^13\). The virtual reality system used in this study was the Wii board balance system, in which users played games while the balancing board sensed weight shift and distribution. The subjects of the virtual reality group performed yoga, muscular strength exercise, aerobic exercise, and balancing exercise, all for 10 minutes each for a total of 40 minutes. The treadmill group used low-speed treadmills for patients to directly control their speed based on their walking ability while walking for 40 minutes. The treadmills were equipped with handles on the front and on both sides, which the users could grip when they lost balance walking. The dashboards on the front showed walking time, distance and calorie consumption.

We used a Pedoscan (RSscan 1m, Germany) to measure balance of the subjects. The device consisted of 4,096 sensors for measuring pressures on both feet in static standing, computerizing left/right weight-bearing and anterior/posterior weight-bearing by separating each area. The patients were asked to stand up straight on the device without any movement for 30 seconds. We used a Smart step (Andante, USA) to measure walking. The device was attached to the dominant foot of a subject, measuring the anterior and posterior pressures of the foot by the pressure detecting sensors on its insole. The insole between the foot and the board sensed the vertical reaction force to measure the stance phase, swing phase, cadence of the dominant foot. The measured signals were temporarily saved by the portable compact controller attached to the ankle by receiving the walking data of the subject and then were computerized and calculated. Before the walking exercise, the Smart step insoles were inserted in the shoes and were injected with air to maintain appropriate pressure. After putting on the shoes and being attached to the controller on their ankles, the subjects walked along a straight footpath for 10 meters, looking straight ahead.

Window SPSS 18.0 was used for statistical analysis. A paired t-test was used for before and after comparisons, and an independent t-test was used for a between group comparison with a significance level of \(\alpha=0.05\).

**RESULTS**

For balance, there were significant differences in both the virtual reality group and the treadmill group after completing of the exercise program. For walking, the virtual reality group showed significant differences after completing of the exercise program. Significant differences between the groups were shown in balance after completing of the exercise program (Table 1).
DISCUSSION

Falling can occur in all age groups, but older people and patients show higher frequency of falling. Planned and consistent exercise is needed to prevent falling and strengthen muscles, and exercises promoting weight bearing, resistance, and aerobic process are known to be effective for such purposes\textsuperscript{14}. Exercises enhancing lower limb muscular strength are sufficiently effective. Exercises for lower limb muscular strength and balancing exercises are effective for the prevention of falling and improvement of stamina of patients, but such exercises have some demerits because the content is simple and thus boring. To supplement the demerits, new methods of exercise owing to development of scientific techniques have been recently introduced where patients can perform various tasks in virtual reality\textsuperscript{15, 16}. Therapeutic intervention via virtual reality is more advantageous than other intervention methods in that it can provide relatively easy environmental control, availability in selecting environments, training based on patients’ abilities via phase-in task difficulty, rapid and precise feedback on performing tasks, and self-learning in safe environment\textsuperscript{17–19}.

We applied an eight-week exercise program to stroke patients who were divided into a virtual reality exercise group and a treadmill walking group, in order to investigate effects of each exercise on balance and walking. The results of measuring balance and walking effects as the purpose of the virtual reality exercise program showed that significant differences were shown in all the domains of the left/right and anterior/posterior weight-bearing in balancing and the stance phase, the swing phase, and the cadence in walking. For the treadmill group, significant differences were displayed in the left/right and anterior/posterior weight-bearing in balancing. Although the walking exercise program using a treadmill showed significant differences in balancing ability, the exercise program using virtual reality training displayed significant differences in balancing and walking because the patients could directly adjust their weight center and shift due to visual feedback. In addition, various similar programs such as jogging may further influence their balancing and walking. The results of this study suggest that virtual reality training may be appropriate to provide planned and consistent exercises for stroke patients who need improved balance and walking ability by giving visual feedback to induce their interest.

Meanwhile, the results of this study are consistent with those reporting increases in left/right, anterior/posterior stability of stroke patients who performed virtual reality training, or reporting significant improvement in the Berg Balance Test for the elderly who underwent a training using virtual reality games\textsuperscript{20}. In addition, there were researches in which significant differences were observed in balancing ability of the elderly with their eyes open after they underwent a virtual reality exercise program, or in which significant differences were found in balancing ability of the elderly after an eight-week virtual reality exercise program. Meanwhile, the increase in walking ability shown in this study was consistent with the results of studies in which electrotherapy based on virtual reality significantly increased walking speed of stroke patients, or in which exercise using visual feedback was effective on the walking ability of stroke patients\textsuperscript{8, 14, 21}. In this study also, virtual reality training was effective in producing positive improvements in balance and walking of stroke patients.

However, there remains insufficient research related to virtual reality because the technology has not been fully commercialized yet. Further studies are needed to deal with virtual reality for many patients to use it in performing various indoor exercise programs and developing their abilities.

The results of this study may indicate that virtual reality training providing visual feedback enables stroke patients to directly adjust their wrong weight center and shift visually, and that it is appropriate for the patients who need improved balance and walking ability by inducing their interest for them to perform planned exercise on a consistent basis.

Table 1. The comparison of balance and gait in virtual reality and treadmill

| Period | Virtual reality group (n=20) | Treadmill group (n=20) | M ± SD | M ± SD |
|--------|-----------------------------|-----------------------|--------|--------|
| Left/right weight-bearing (%) | Pre | 17.1 ± 5.5 | 16.9 ± 6.5 |
| | Post | 10.6 ± 4.8** | 13.1 ± 5.8** |
| Anterior/posterior weight-bearing (%) | Pre | 15.4 ± 6.7 | 15.7 ± 4.6 |
| | Post | 10.3 ± 4.7** | 12.9 ± 5.1** |
| Affected side stance phase (%) | Pre | 53.7 ± 6.4 | 54.2 ± 7.6 |
| | Post | 57.5 ± 5.7* | 55.3 ± 6.4 |
| Affected side swing phase (%) | Pre | 46.2 ± 6.4 | 45.7 ± 7.6 |
| | Post | 42.4 ± 5.7* | 44.6 ± 6.4 |
| Cadence (steps/min) | Pre | 44.2 ± 5.4 | 43.7 ± 6.4 |
| | Post | 48.1 ± 6.1* | 45.2 ± 6.1 |

*paired t-test, †independent t-test, *p<0.05, **p<0.01
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