Effects of vestibular rehabilitation on gait performance in poststroke patients: a pilot randomized controlled trial

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The effects of vestibular rehabilitation on poststroke patients are unknown. This study aimed to investigate whether or not vestibular rehabilitation would improve both the vestibulo–ocular reflex and gait performance of patients with poststroke hemiparesis. Twenty-eight patients with stroke were assigned randomly to either an experimental group (*N*= 14) or a control group (*N*= 14). The experimental group performed the conventional physical therapy for 40 min and vestibular rehabilitation for 20 min, as a 60 min session, during the first 3 weeks and then completed only the conventional intervention for 60 min for the following 3 weeks. The control group performed only the 60 min conventional physical therapy for 6 weeks. Both groups were measured using the gaze stabilization test, the 10 m walking test, the timed up and go test, and the dynamic gait index. Patients were assessed at baseline, and at 3 and 6 weeks. Although the control group showed no significant difference in any outcome measures, the experimental group showed an improvement in gaze stabilization test scoring, which increased significantly after 3 weeks compared with the baseline (*P*= 0.030). The dynamic gait index was also significantly increased after 3 and 6 weeks compared with the baseline (*P*= 0.049 and 0.024, respectively). This study indicated that vestibular rehabilitation might improve poststroke patients' vestibulo–ocular reflex. Moreover, patients might show improved gait performance at least up to 3 weeks after the vestibular intervention by the sensory reweight to coordinate vestibular input. *International Journal of Rehabilitation Research* 00:000–000 Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

International Journal of Rehabilitation Research 2017, **00:**000–000

Keywords: dynamic gait index, gait performance, gaze stabilization test, stroke, vestibular rehabilitation, vestibulo–ocular reflex

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Received 13 March 2017 **Accepted** 4 May 2017

Introduction

The reflex mechanism related to vestibular function plays an important role in postural control. It has been suggested that the vestibulo–ocular reflex (VOR) is activated to gaze on a target during head rotation and to maintain one's posture (Jull *et al.*, 2008). In terms of gait performance, a previous study has shown that the VOR function is significantly related to gait performance and evaluation of the VOR may be beneficial for identifying individuals at risk for falling (Honaker *et al.*, 2013).

Research in neurological diseases reported that patients with poststroke hemiparesis showed more risks of falling than healthy individuals (Jørgensen *et al.*, 2002). Also, poststroke patients lose standing postural stability more compared with healthy individuals when administered galvanic vestibular stimulation (Bonan *et al.*, 2013). It is possible that poststroke patients have a high risk of falling because of vestibular dysfunction. Thus, simultaneously measuring changes in the VOR function and gait performance before and after intervention with a focus on the vestibular system will provide valuable information for clinical rehabilitation.

Some studies have reported the benefit of vestibular rehabilitation to facilitate the reflex mechanism related to vestibular function (Strupp *et al.*, 1998; Corna *et al.*, 2003). It is suggested that the sensory conflict might lead to neurological rearrangements, known as vestibular compensations, on which the rationale of the VOR training is based (Hansson *et al.*, 2004; Schubert *et al.*, 2008; Vereeck *et al.*, 2008). The main components of vestibular rehabilitation are gaze stabilization exercises to help adapt the VOR function and balance exercises, as substitution exercises, to retrain the vestibulo–spinal reflex function (Herdman, 1989; Herdman *et al.*, 2003). Previous studies have already shown that vestibular rehabilitation improved postural stability in patients with central and peripheral vestibulopathy (Strupp *et al.*, 1998; Clendaniel, 2010); however, the effects of vestibular rehabilitation on poststroke patients are unknown. Patients in hospitals are required to show maximized recovery within a limited time before returning home. From this point of view, vestibular rehabilitation can be easily performed at home without any complex exercise tools or a spacious room (Dai *et al.*, 2013). Theoretically, patients with stroke hemiparesis could also gain

DOI: 10.1097/MRR.0000000000000234

improvements in both the VOR function and gait performance by vestibular rehabilitation therapy, similar to patients with vestibular disease.

The aim of this study was to determine whether or not vestibular rehabilitation improves both the VOR function and the gait performance of patients with stroke. It was hypothesized that patients with stroke hemiparesis would show improved gait performance after intensive vestibular training compared with conventional rehabilitation.

Patients and methods

Participants

Patients were recruited from a rehabilitation hospital between March 2014 and November 2016. All patients were diagnosed with hemiplegic stroke by physicians, computed tomography, and/or a MRI scan of the brain. Stroke was defined as an acute event of cerebrovascular origin diagnosed by a neurologist. Patients had to have (a) hemorrhagic or ischemic strokes during inpatient at hospital, and first-time stroke with a duration of less than 6 months from the onset of stroke; (b) the ability to walk without support for at least 30 m; and (c) the ability to perform the gaze stabilization test (GST). Patients were excluded if they (a) presented a neurological condition unrelated to stroke hemiparesis condition that would affect postural stability; (b) had vestibular symptoms including dizziness or vertigo; and (c) could not provide informed consent for study participation.

Clinical status was assessed by skilled nurses and therapists with respect to motor impairment using the Fugl-Meyer assessment scale for the lower extremity (FMA-LE) (Fugl-Meyer *et al.*, 1975). Also, patients' daily activities were measured by the functional independence measure (FIM) (Granger *et al.*, 1993).

Study protocol

This study was a single-blinded (evaluator) randomized-controlled trial. A total of 124 patients volunteered for this study; of these, 36 patients who fulfilled all criteria were assigned randomly to the experimental or control groups by RAND function (Microsoft Office Excel 2013; Microsoft Corp., Redmond, Washington, USA). They were assigned to one of two groups on the basis of the size of the random number. In other words, those with higher numbers were assigned to one group and those with lower numbers were assigned to the other group. This assignment task was performed by a third party completely unaware of the study content, and individuals who collected the outcome data and performed the outcome assessments were also blinded to the group membership. This study was approved by the local ethics committee and participants provided their written informed consent. The study was registered with the rehabilitation hospital and university (trial registration numbers 20134 and 25-15).

Both groups received a conventional rehabilitative intervention, including physical therapy focusing on improving muscle strength, postural, and gait control. The program included a range-of-motion exercise for the limbs and trunk, muscle strengthening, walking indoors and outdoors, and climbing up and down stairs. The experimental group performed this conventional intervention for 40 min and vestibular rehabilitation for 20 min, as a 60 min session, during the first 3 weeks and then completed the conventional intervention only for 60 min for the following 3 weeks (Fig. 1). The control group completed the conventional rehabilitative intervention only for 60 min every day for 6 weeks (Fig. 1).

Vestibular rehabilitation program

The vestibular rehabilitation program consisted of two major components: vestibular adaptation and balance exercises under the supervision of a physiotherapist (Giray *et al.*, 2009; Balci *et al.*, 2013).

To improve gaze stability, patients were initially asked to keep their eyes on the stationary target of a medium position while continuously moving the head horizontally (VOR × 1) and they were then asked to perform the same head rotation while moving the target to the opposite directions to the head simultaneously (VOR × 2). Patients were asked to repeat the head movement as fast as possible while maintaining focus on the target. The exercises progressed under more challenging conditions from sitting to standing with feet apart, feet together, and walking.

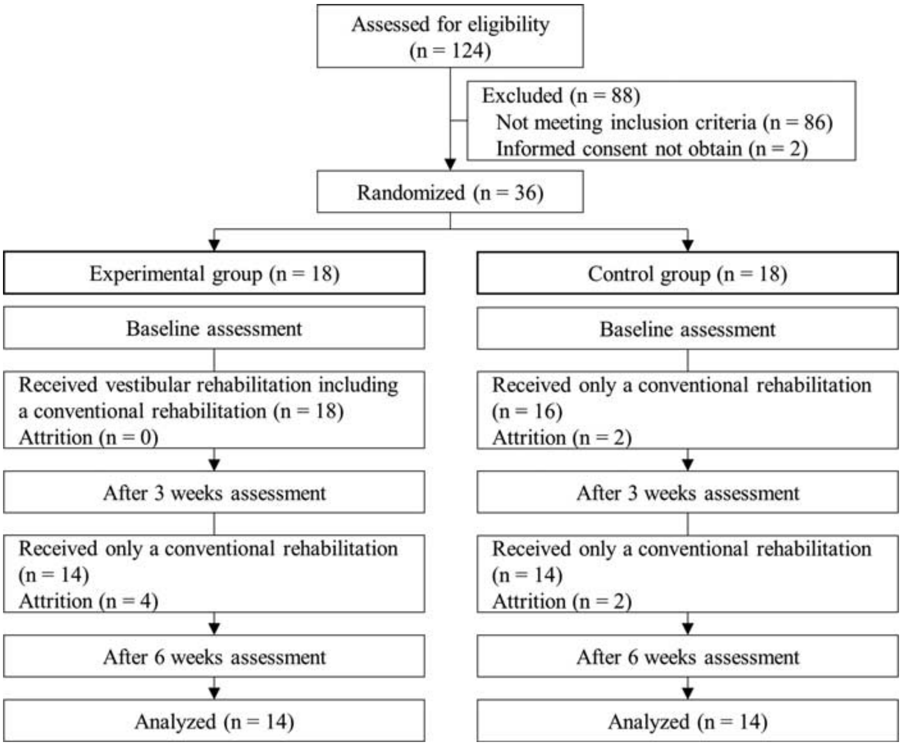
For the balance exercises, patients were asked to maintain balance while rotating their neck and trunk to the right and left, and weight shifting forward-backward and side to side. The difficulty of exercises was increased by changing the bases of support from a firm surface to a foam surface, and by changing from eye-opened to eye-closed conditions. These graded tasks required the enhanced use of visual, proprioceptive, and residual vestibular inputs to stimulate compensation (Murray *et al.*, 2001; Herdman *et al.*, 2003).

Outcome measurements

All patients' VOR and clinical gait performance were evaluated before the intervention, and 3 and 6 weeks after the intervention. The VOR was measured using the GST and gait performance was assessed using the 10 m walking test (10MWT), the timed up and go test (TUG), and dynamic gait index (DGI).

The GST assesses the VOR contribution to visual acuity by identifying the peak head velocity while maintaining visual fixation during head rotation (Lee and Honaker, 2013). Patients were asked to sit on a chair positioned 1.5 m from a computer screen in a well-lit room. An optotype (the letter E) was shown on the screen and patients performed a GST for measurement of

Fig. 1



Flowchart of patients.

head velocity using a head-mounted accelerometer (TSND121; ATR-Promotions, Kyoto, Japan) and for monitoring of head movement using a movie (Lavie LX750/L webcam; NEC, Tokyo, Japan). Head movement was recorded at a sampling rate of 1 kHz. Head velocity and movie were synchronized using analysis tools [SyncRecord (T); ATR-Promotions].

Procedure

For GST methods, first, to measure the static visual acuity, the patients were asked to report in one of four orientations (up, down, left, or right) of the optotype. The optotype size was then adjusted on the basis of the accuracy of the patient's response. The optotype size used at the GST was customized for each patient at 0.2 logMAR units above their static visual acuity. Second, the optotype was shown to the patients for 50 ms. During a training period, patients were familiarized with the passive head movement at a consistent head velocity with a position amplitude of less than 20° from the midline in the yaw plane (Lee and Honaker, 2013). The actual testing began using a head velocity of 40°/s, which was progressed in increments to three fixed speeds of 70°, 100°, and 130°/s. A computer screen presented the optotype of fixed size and random orientation. Patients who correctly identified the optotype orientation three times out of five presentations then proceeded and were asked to increase the speed of head movement, whereas those who made three or more errors were presented the optotype at a slower head speed (Lee and Honaker, 2013). To test the repeatability of the GST, it was completed by 10 random patients on two different days and the intracorrelational coefficient for the between-day measurements of the GST was assessed. The intracorrelational coefficient was 0.842, which indicated a high level of repeatability.

For the 10MWT, patients were asked to walk at the maximum speed for 16 m. The time taken to walk the middle of the 10 m on the track was recorded. Patients performed the test twice and their completion times were averaged.

The TUG test measured the time taken to stand up from a chair (46 cm chair height), walk a distance of 3 m, turn, walk back to the chair, and sit down (Mathias *et al.*, 1986). Patients performed the test twice and their completion times were averaged.

The DGI was used to assess gait instability. This test consisted of eight tasks including walking at their own pace, walking at different speeds, walking with head movement, walking with a quick turn and stop, walking over and around objects, and walking up stairs (Shumway-Cook and Woollacott, 1995). The examiner

Table 1 **Characteristics of the patients**

Characteristics	Experimental group ($n=14$)	Control group ($n=14$)
Age (years)	67.6 (9.0)	68.1 (13.5)
Sex (male/female)	11 (78.6)/3 (21.4)	11 (78.6)/3 (21.4)
Lesion (supratentorial/ infratentorial)	10 (71.4)/4 (28.6)	10 (71.4)/4 (28.6)
Affected side (right/left)	8 (57.1)/6 (42.9)	7 (50.0)/7 (50.0)
Time since stroke (days)	52.4 (26.4)	64.1 (37.7)
Fugl-Meyer assessment for the lower extremity (scores)	27.7 (5.6)	27.6 (6.4)
Functional independence measure (scores)	101.2 (15.2)	105.4 (11.6)

Values are given as mean (SD) or *n* (%).

scored the performance from 0 (poor) to 3 (excellent) for each task. Higher scores indicate better performance, with a maximal score of 24 (Shumway-Cook *et al.*, 1997; Whitney *et al.*, 2000).

Statistical analysis

All data analyses were carried out using IBM SPSS Statistics 23 (IBM Corp., Armonk, New York, USA). First, unpaired *t*-tests and a Mann–Whitney *U*-test were used to evaluate differences in age, time since stroke, FMA-LE, and FIM baseline characteristics between the experimental and control groups. χ^2-Tests were used to assess the number of patients by sex and affected side between groups. Second, a two-way repeated-measures analysis of variance was used for group differences (experimental vs. control groups) and for times (baseline, after 3 weeks, after 6 weeks) to determine whether there were significant differences in the GST, 10MWT, TUG, and DGI. A post-hoc test with Bonferroni correction was used in multiple comparisons both between and within groups. The effect sizes (Cohen's d) were calculated using the mean differences of the changes after 3 and 6 weeks compared with the baseline. Significance level was set at 0.05.

Results

With randomization, 18 patients were assigned to the experimental group and 18 patients were assigned to the control group. During the initial 3 weeks, two patients in the control group dropped out because they were discharged from the hospital, transferred to other facilities, and/or had aggravated symptoms. Between the fourth week and the sixth week, 4 patients in the experimental group and two patients in the control group dropped out for the same reasons. As a result, 14 patients in the experimental group and 14 patients in the control group completed the entire study with no adverse events (Fig. 1).

The demographic characteristics of the two groups are presented in Table 1. There were no significant differences at baseline between the experimental and the control groups in age, sex, lesions area, affected side, or the time since stroke, FMA-LE, or FIM. Changes in the main outcome measures are shown in Table 2. A repeated-measure analysis of variance showed a significant effect of time (GST; $F=4.784$, $P=0.011$, 10MWT; $F=5.080$, $P=0.008$, TUG; $F=3.941$, $P=0.023$, and DGI; $F=6.607$, $P=0.002$). In the experimental group, post-hoc tests showed that the GST increased significantly after 3 weeks compared with the baseline ($P=0.03$, $d=1.05$) and the DGI increased significantly after 3 and 6 weeks compared with the baseline ($P=0.049$, $d=0.96$, and $P=0.024$, $d=1.10$, respectively). There were no significant differences in the control group in any of the main outcome measures.

Discussion

The results of this study indicated that the experimental group showed a significant increase in the GST 3 weeks after the intervention compared with the baseline. The GST was introduced as an evaluation of the VOR function without visual acuity influence (Goebel *et al.*, 2007). It has been reported that the head rotation exercise improves the VOR adaptation even in a short-term intervention (Migliaccio and Schubert, 2014). Thus, findings suggested that vestibular rehabilitation might improve the VOR function in poststroke patients.

In terms of the continuous effects of the vestibular rehabilitation, the experimental group showed no difference in the GST 6 weeks after the intervention compared with the baseline; however, a larger effect size was found. The small sample size and large SD might have resulted in the null findings in the GST score. However, the DGI of the experimental group improved significantly not only 3 weeks after the vestibular rehabilitation but also 6 weeks after the intervention compared with the baseline. The DGI was used to evaluate and document a patient's ability to modify gait in response to changing task demands (Shumway-Cook and Woollacott, 1995). A previous study has shown that there were significant positive correlations between the VOR function and the DGI in individuals with vestibular disorders (Whitney *et al.*, 2009). In the postural control function, the sensory strategy consists of the visual, somatosensory, and vestibular system, and poststroke patients tend to show an increase in postural perturbation because of understimulations in one of the sensory strategies (Bonan *et al.*, 2013; Bonan *et al.*, 2016). In particular, patients with hemiplegia cannot adequately utilize vestibular information, and instead, rely considerably on visual input for stabilizing their postures (Bonan *et al.*, 2004). Vestibular rehabilitation fosters the sensory reweight to coordinate vestibular input (Marioni *et al.*, 2013), and as a result, patients might show improved walking performance at least up to the 3 weeks after the vestibular intervention.

In terms of time since stroke, vestibular rehabilitation research has already shown significant improvements in DGI by vestibular exercises in patients who have had an

Table 2 **Changes in outcome measures in both the experimental and the control groups**

				Baseline vs. 3 weeks		Baseline vs. 6 weeks	
	Baseline	3 weeks	6 weeks	*P*	*d*	*P*	*d*
Experimental group (*n* = 14)							
Gaze-stabilization test (deg/s)	82.82 (22.26)	110.96 (30.90)	108.35 (28.47)	0.030	1.05	0.055	1.00
10 m Walking test (m/s)	0.69 (0.34)	1.03 (0.61)	1.09 (0.58)	0.290	0.69	0.159	0.84
Timed up and go test (s)	23.18 (12.23)	15.65 (10.44)	14.63 (10.54)	0.241	0.66	0.145	0.75
Dynamic gait index (scores)	11.29 (6.46)	17.50 (6.43)	18.36 (6.43)	0.049	0.96	0.024	1.10
Control group (*n* = 14)							
Gaze-stabilization test (deg/s)	83.58 (29.32)	93.91 (29.47)	99.54 (26.62)	1.000	0.35	0.440	0.57
10 m Walking test (m/s)	0.69 (0.38)	0.95 (0.44)	1.08 (0.47)	0.369	0.63	0.066	0.91
Timed up and go test (s)	23.40 (14.27)	17.35 (11.60)	15.31 (11.33)	0.622	0.47	0.282	0.63
Dynamic gait index (scores)	11.71 (6.41)	14.86 (6.50)	16.71 (6.52)	0.612	0.49	0.131	0.77

Values are mean (SD).

acute stroke (Balci *et al.*, 2013). The results of this study showed that patients with subacute stroke also showed significant improvements in the DGI after vestibular rehabilitation. Thus, our results extended previous findings and indicated a crucial role of the vestibular rehabilitation in subacute poststroke patients' gait performance.

The current study has several limitations. First, although there were many potential patients at the beginning of the study, the number of patients decreased because of stringent inclusion/exclusion criteria, it was difficult to conduct this study because patients were discharged promptly due to their mild physical dysfunction. There was no significant improvement in any outcome measures in the control group, which performed only regular rehabilitation during the intervention period. It was crucial to include a stroke group with high physical performance to precisely evaluate the effect of vestibular rehabilitation with the expectation that those with high physical function would likely be discharged from the hospital soon. Second, examiners evaluating the clinical practicality of vestibular rehabilitation were not blinded to the treatments, which might have influenced the results. Third, it is difficult to determine which areas of cerebral injuries actually affected the VOR function and gait performance. In future studies, it is important to investigate the relationship between the location of cerebral injuries and the effect of vestibular rehabilitation. Finally, given that the main aim of vestibular rehabilitation is to decrease the risk of falling, it would be interesting to register eventual falls among stroke patients. None of the patients in the present study had fall accidents during this study period, possibly because they were still in the hospital and were being closely monitored. Examination of how long the short-term vestibular rehabilitation is effective after discharge from the hospital to prevent falls is warranted in future studies.

Despite these limitations, the present study showed that vestibular rehabilitation could improve both the VOR and the walking performance, even though poststroke was not directly associated with vestibular syndrome including vertigo. This suggests that the vestibular system plays an important role in maintaining balance for poststroke patients and it is beneficial to include vestibular rehabilitation in poststroke patients' daily rehabilitation routine. Therefore, it is critical for clinicians to pay more attention to not only common vestibular symptoms such as vertigo but also gait stabilization to avoid falls and further injuries.

Conclusion

This study indicated that vestibular rehabilitation might improve poststroke patients' VOR. Moreover, patients might show improved gait performance at least up to 3 weeks after the vestibular intervention by the sensory reweight to coordinate vestibular input.

Acknowledgements

The authors thank Bradford Pomeroy for his help in preparing the manuscript. They also thank the participants for their time and effort.

This work was supported by grant number 3 from the Japanese Society for the Promotion of Rehabilitation in 2016.

Conflicts of interest

There are no conflicts of interest.

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