Observational Study

Medicine®

OPEN

Effects of stabilizing reversal technique and vestibular rehabilitation exercise on dizziness and balance ability in patients with vestibular neuritis

An observational study

Beomryong Kim, PhD[a,c], Everett Lohman, DSc[b], JongEun Yim, DSc[c,*]

Abstract

Vestibular neuritis is a common disease of peripheral dizziness. Studies have shown that vestibular rehabilitation exercise (VRE) and proprioceptive neuromuscular facilitation (PNF) are effective to treat the symptoms of vestibular neuritis. However, the effect of VRE and PNF on the balance ability and dizziness in this patient cohort remains unclear.

The aim of our observational study was to determine the changes in dizziness and balance ability of patients with vestibular neuritis who participated in the VRE program with stabilizing reversal technique (SRT).

The reporting of this study conforms to the STROBE statement. Ten men and women aged ≥ 20 years who were diagnosed with vestibular neuritis were included. Patients performed VRE with SRT for 4 weeks with assistance from a therapist. VRE without SRT can also be performed at home. Dizziness was evaluated using the dizziness handicap inventory (DHI) and visual analog scale (VAS). Balance ability was assessed using the Berg's balance scale (BBS) and timed up and go test (TUG). At pre- and post-exercise, paired *t* test was performed to compare the within-group differences.

After the program, DHI (45.40 ± 6.74 to 21.00 ± 7.07), VAS (5.90 ± 1.20 to 2.80 ± 0.92), BBS (45.10 ± 2.77 to 52.70 ± 1.83), and TUG (15.29 ± 1.13 to 12.06 ± 1.61) scores improved significantly in the VRE program group ($P = .05$).

The VRE program combined with SRT was effective in reducing dizziness and increasing balance ability in patients with vestibular neuritis.

Abbreviations: BBS = Berg's balance scale, DHI = dizziness handicap inventory, PNF = proprioceptive neuromuscular facilitation, SRT = stabilizing reversal technique, TUG = timed up and go test, VAS = visual analog scale, VRE = vestibular rehabilitation exercise.

Keywords: balance ability, dizziness, stabilizing reversal technique, vestibular neuritis, vestibular rehabilitation

Editor: Gopal Nambi.

This study was supported by Sahmyook University Research Fund (RI12020035).

No competing financial interests exist.

The authors declare no conflicts of interest.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

[a] Department of Physical Therapy, Design Hospital, Jeonju, Republic of Korea, [b] Department of Physical Therapy, School of Allied Health Professions, Loma Linda University, Loma Linda, CA, [c] Department of Physical Therapy, The Graduate School of Sahmyook University, Seoul, Republic of Korea.

[*] Correspondence: Jongeun Yim, Department of Physical Therapy, College of Health Science and Social Welfare, Sahmyook University, 815, Hwarang-ro, Nowon-gu, Seoul 01795, Republic of Korea (e-mail: jeyim@syu.ac.kr).

How to cite this article: Kim B, Lohman E, Yim J. Effects of stabilizing reversal technique and vestibular rehabilitation exercise on dizziness and balance ability in patients with vestibular neuritis: An observational study. Medicine 2022;101:4 (e28740).

Received: 6 August 2021 / Received in final form: 19 December 2021 / Accepted: 8 January 2022

http://dx.doi.org/10.1097/MD.0000000000028740

1. Introduction

Vestibular neuritis is the second most common disease of peripheral dizziness and occurs in approximately 7% of patients with dizziness.[1] Its incidence rate for 1 year is 11.7 to 15.5 per 100,000 people, with the highest frequency of occurrence in 40 to 50-year-old patients; unlike other types of peripheral dizziness, vestibular neuritis has the same occurrence in men and women.[2] Generally, vestibular neuritis invades the superior vestibular nerve. As a cause of occurrence, various hypotheses have been proposed. Of these, viral infection of the vestibular nervous system or ischemia of the internal ear is reported to be the cause of vestibular neuritis.[3]

The viral infection hypothesis of the vestibular nervous system indicated that the antibody titer of herpes simplex virus, herpes zoster virus, cytomegalovirus, Epstein–Barr virus, rubella virus, adenovirus, and influenza virus is increased in the serological test of the patient.[4] However, evidence to support the development of peripheral vestibular neuritis due to viruses is lacking, and no virus has been proven to be a direct cause. The labyrinthine artery, which branches from the anterior inferior cerebellar artery, is divided into the common cochlear and anterior vestibular arteries. The anterior vestibular artery provides a similar blood flow to the semicircular canals (anterior, posterior, and horizontal) and macula of utricle, similar to the superior bronchus of the vestibular nerve. Vestibular neuritis and its clinical aspects are similar to cases of selective ischemia of the anterior vestibular artery. However, the possibility of selective ischemia of the anterior vestibular artery is not high, and hypacusis and brainstem symptoms are usually accompanied by extensive ischemia of the anterior inferior cerebellar artery region.[5] Therefore, the cause of vestibular neuritis remains unknown.

There is usually a quick decline in the clinical characteristics of vestibular neuritis within a few days owing to static vestibular imbalances, such as vertigo, nystagmus, ocular tilt reaction, and posture deviation. On the contrary, the disability caused by a dynamic vestibular imbalance, such as a nystagmus, induced by vibration stimulus, head thrust test, caloric test, and rotary chair test, persists for a long time.[6] Severe vertigo causing dysfunction has disappeared in 70% of patients with vestibular neuritis within 1 week (mean: 2–3 days), and severe vertigo in 2 weeks or more has been reported in 4% of the cases.[7]

Vestibular neuritis is a disease diagnosed based on exclusion. Specific tests cannot diagnose vestibular neuritis. Therefore, it is diagnosed by synthesizing characteristic clinical aspects and several vestibular function test results. The caloric test can detect unilateral vestibular function loss.[8] The vestibular-evoked myogenic potential (VEMP) test is useful for distinguishing between the hypo-function of the vestibular organ and the superior and inferior vestibular nerves of vestibular neuritis.[9,10] A rotary chair test is useful for the early diagnosis of bilateral vestibular organ problems[11,12]; in addition, a diagnosis of vestibular neuritis is made using the Romberg test, dynamic visual acuity, subjective visual vertical, bucket test, frenzel goggles, magnetic resonance imaging (MRI), and computed tomography (CT).[13]

The mechanisms of spontaneous recovery, vestibular adaptation, and substitution are involved in the recovery from vestibular function disorders. It is associated with recovery during rehabilitation exercise. Spontaneous recovery occurs during nystagmus, skew deviation, and postural asymmetry. The vestibulo-ocular reflex and vestibulo-spinal reflex dysfunction recover naturally when there are peripheral vestibular function disorders.[14] The vestibular adaptation is due to the adaptability of the vestibular organ, in part, to recover its vestibulo-ocular reflex in peripheral vestibular disorder. This is the long-term adaptation of the vestibular system in response of the nervous system to information coming from the head movement.[15] Substitution is a vestibular function disorder that replaces the vestibular function with a body action that substitutes other functions, such as visual and somatosensory functions.

Moreover, problems in maintaining balance and dizziness due to dynamic vestibular imbalance persist in patients with vestibular neuritis. For recovery of these vestibular functions, adaptability through various external stimuli should be developed. It is necessary to further improve visual and somatosensory functions to replace vestibular function. Therefore, a method designed by Cawthorne and Cooksey for performing vestibular rehabilitation exercise (VRE) has been applied.[16,17]

Proprioceptive neuromuscular facilitation (PNF) is a functional movement pattern in different directions, including flexion, extension, abduction, adduction, and rotation. PNF is an interventional concept that facilitates the motor response of the subject and enhances neuromuscular function and control using functional movement patterns and techniques.[18] The purpose of PNF is to enhance the functional movement through facilitation, inhibition, reinforcement, and relaxation of muscle groups.[19]

Among the techniques of PNF, the stabilizing reversal technique (SRT) has been used for the purpose of enhancing posture stability and balance by inducing alternation or co-contraction of agonist and antagonist muscles without causing motion or movement against subject's resistance to a therapist.[19] Jung and Chung[20] showed that the hip joint strengthening exercise program, including SRT, improved the balance ability of traumatic brain injury patients. Cayco et al[21] reported that PNF, including SRT, was effective in improving the balance ability of the elderly with chronic stroke and in alleviating the fall risk.

Thus, studies have shown that PNF, including SRT, is effective in improving balance ability in patients with a brain injury. However, there have been only a few studies on the effect of VRE and SRT of PNF on the balance ability and dizziness on patients with vestibular neuritis. Therefore, this study aimed to determine the changes in dizziness and balance ability of patients with vestibular neuritis who participated in the VRE program combined with SRT of PNF.

2. Materials and methods

2.1. Participants

Ten men and women aged 20 years who were diagnosed with vestibular neuritis by a doctor at the D hospital otolaryngology in J city from March 2019 to August 2019 and who received a VRE prescription were included in this study. A study flow diagram is presented in Figure 1. The study was approved by the Institutional Review Board of the Sahmyook University (IRB No. 2–7001793-AB-N-012019016HR) in Seoul.

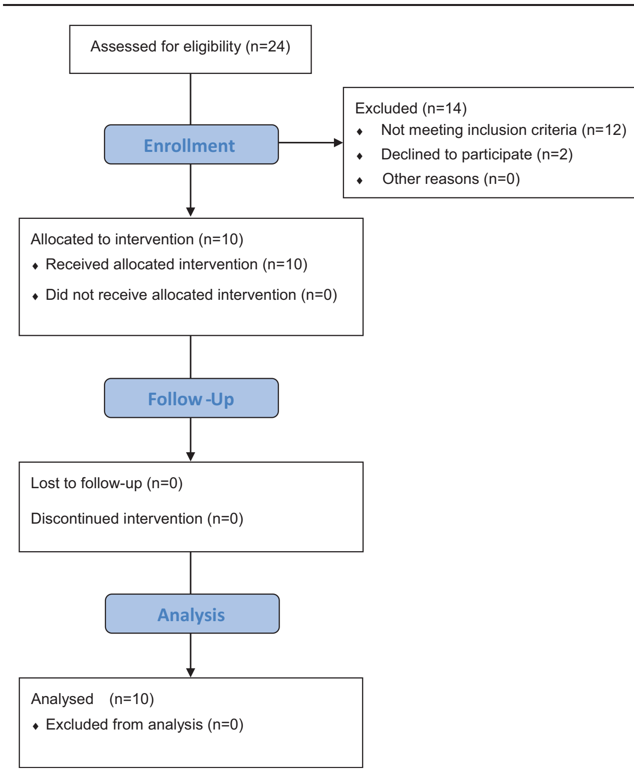

Figure 1. Study flow diagram.

Table 1

Physical characteristics of subjects (N = 57).

	Experimental group (n = 31)	Control group (n = 26)
Age	78.13 ± 4.76	78.77 ± 4.80
Gender (male/female)	10/21	9/17
Height, cm	156.15 ± 8.72	157.14 ± 8.67
Weight, kg	62.17 ± 8.34	61.53 ± 8.63
BMI	25.54 ± 3.17	24.83 ± 2.38

Mean ± SD.

The diagnosis of vestibular neuritis was made when the following four diagnostic criteria for vestibular neuritis were met: rotational aquatic vertigo, nausea, and postural instability occurring within a matter of hours; when a horizontal spontaneous nystagmus with a rotational component on the physical examination appearing on the unaffected side, with the patient not reporting any central dizziness; the head impulse test on the lesion side showing eye saccade and smooth pursuit eye movement; and the caloric test showing more than 25% canal paresis on the lesion side.

The selection criteria for the patients in this study were as follows: those who were diagnosed with vestibular neuritis, who were first trained in VRE, and who were able to understand and respond to the questionnaire survey. Patients with previously diagnosed vestibular dysfunction with cochlear symptoms, such as tinnitus or acute sudden sensory neural hearing loss, are accompanied by cerebropathy, those diagnosed with dizziness (central, psychogenic, cervicogenic) other than vestibular neuritis, and those with limitation of movement due to a musculoskeletal disorder were excluded from the study. The general characteristics of the patients are presented in Table 1.

2.2. Intervention and procedure

The VRE program of this study was based on the devised VRE method of Cawthorne and Cooksey, [16,17] which combined the PNF concept. The details of VRE are as follows: In a 90-degree hook lying position, the participants performed superior/inferior and left/right eye movement slowly and then accelerating (A exercise). Then, the patients shifted their focus on their fingers and moved their head to the superior/inferior and left/right sides slowly, then accelerating. Later, the exercise was performed with eyes closed (B exercise). At this time, the therapist placed a hand on the knee and applied the SRT to increase the trunk stability by instructing the patient to push against the therapist hands. Next, in the sitting and standing positions, the therapist stood behind the patient and placed his hand on the shoulder and performed A and B exercises with SRT. The balance walking exercise was performed with the patient's eyes opened and focusing on one target on the floor in front while walking; then, the next step was to focus on the target and walk with the eyes closed. Then, the patient was instructed is to imagine the focus on the target and move the head to the left/right and superior/inferior to perform a walking exercise. At this time, the therapist accompanied the patient to help them avoid falling down. All exercises with therapist assistance were performed for 30 minutes including break time, 3 times a week for 4 weeks. The patients were instructed to perform the VRE, without SRT, for 30 minutes a day for 4 weeks at home.

2.3. Outcome measurements

The dizziness handicap inventory (DHI) is a method for identifying the effects of dizziness and unsteady state on the quality of life of a person and to outcome subjective results that aid in quantification. DHI consists of 25 items in total (7 physical items, 9 emotional items, 9 functional items). The degree of disability is scored as follows: 4 for "Yes," 2 for "Sometimes," and 0 for "No." The total score ranges from 0 (no recognized disorders) to 100 (maximum recognized disorders). The questionnaire originated from the records of patients who reported dizziness.[22] Jacobson and Newman[22] confirmed high confidence between test and retest.

To measure the degree of dizziness, the subject was personally examined using a visual analog scale (VAS). A personal check was made on a piece of paper marked with 10 intervals with 0 for no dizziness and 10 for maximum dizziness. This test tool has a test-retest reliability [intraclass correlation coefficient (ICC) = 0.96].[23]

Berg's balance scale (BBS) is a tool for objectively evaluating static and dynamic balance ability, and it quantitatively evaluates balance ability and fall risk by directly observing performance of the elderly.[24] Fourteen items are assessed to determine the patients' ability to maintain balance through sitting, standing, and postural changes, and about 20 minutes are taken. If the items cannot be performed at minimum, 0 points are given, and for completely independent, the maximum of 4 points is noted, and the total points are 56. A score of 0 to 20 indicates a severe balance disorder, a score of 21 to 40 indicates a slight balance disorder, and a score of 41 to 56 indicates good balance ability. This tool has high validity, intra-rater reliability (ICC = 0.97), inter-rater reliability (ICC = 0.95–98), and test-retest reliability (ICC = 0.98).[25]

Timed up and go test (TUG) is a tool for measuring mobility and balance quickly. The subject is seated on a chair with 46 cm high armrests. The subject is then signaled to get up from the chair, walk 3 m away from the chair, turn around, and then sit back down on the chair with a quick pace. The time taken by the subject to perform this task is then recorded. The average time was recorded by repeating the measurement three times. This test tool has intra-rater and inter-rater reliability (ICC = 0.98–0.99).[26]

2.4. Statistical analysis

Statistical analysis was performed using SPSS/PC Statistics 18.0 software for Windows (SPSS Inc., Chicago, IL). The paired t test was performed to compare the differences in dizziness and balance abilities in the experimental group before and after VRE. All statistical significance levels were set at a P value of less than .05.

3. Results

3.1. Measurement change in dizziness

The DHI-physical changes in the experimental group before and after the exercise decreased from 14.80 ± 2.15 to 6.20 ± 3.05, showing statistically significant results (t = 11.73; P < .05; 95% confidence interval [CI], 6.94–10.26). The DHI-emotional changes in the experimental group before and after exercise decreased from 14.20 ± 2.74 to 5.60 ± 2.95, showing statistically significant results (t = 20.15; P < .05; 95% CI, 7.63–9.57). The

DHI-functional changes in the experimental group before and after exercise decreased from 16.40 ± 2.63 to 9.20 ± 3.42, showing statistically significant results (t = 8.43; P < .05; 95% CI, 5.27–9.13). The DHI-total changes in the experimental group before and after exercise decreased from 45.40 ± 6.74 to 21.00 ± 7.07, showing statistically significant results (t = 23.82; P < .05; 95% CI, 22.08–26.72).

The VAS changes in the experimental group before and after exercise decreased from 5.90 ± 1.20 to 2.80 ± 0.92, showing statistically significant results (t = 11.20; P < .05; 95% CI, 2.47–3.73) (Table 2).

3.2. Measurement change in balance

The BBS changes in the experimental group before and after exercise increased from 45.10 ± 2.77 to 52.70 ± 1.83, showing statistically significant results (t = -6.57; P < .05; 95% CI, -10.22 to -4.98).

The TUG changes in the experimental group before and after exercise decreased from 15.29 ± 1.13 to 12.06 ± 1.61, showing statistically significant results (t = 11.43; P < .05; 95% CI, 2.59–3.87) (Table 3).

4. Discussion

The purpose of VRE is to restore the activity of everyday life by improving the balance ability of patients with decreased vestibular function, promoting safety during walking and related movements, and reducing the symptoms of the patient, that is, dizziness. In this study, we investigated the effect of the VRE program with SRT of PNF on the dizziness and balance ability of patients with vestibular neuritis. The results of this study showed that there was a significant decrease in dizziness after VRE with SRT in the experimental group.

In the study by Sparrer et al[27] who divided their patients into the experimental group who performed customized exercise using the Nintendo Wii Balance Board with medication treatment, and a control group who performed exercise with medical treatment for patients with vestibular neuritis, a significant decrease in dizziness was observed in the experimental group, and the patients' return to everyday life was faster in the experimental group than in the control group. Crane and Schubert[28] showed an average decrease of 71% in dizziness after one month of implementing a computer-based adaptation of the vestibular rehabilitation program as compared to the traditional VRE. Preceding studies suggest that habituation exercises can reduce symptoms even if the same situation occurs by repeatedly performing various postures or situations in everyday life in which the patient's symptoms occur. This exercise usually involves the head or eyeball to reinforce adaptation of the vestibular organ.[14] In the VRE program of this study, adaptation was reinforced through head and eyeball exercises for various postures of the knee: the 90-degree hook lying position, sitting position, and standing position, suggesting that

Table 2

Changes in 10MWT and functional strength before and after the treatment (N = 57).

			Interaction (Group X Time)		
Group	Pre-exercise	Post-exercise	Effect size d	*F*	*P*
10 MWT, s					
tDCSG	8.02 ± 1.29	7.56 ± 1.02*	0.673	6.180	.016
CG	7.80 ± 1.11	7.68 ± 1.11			
5STST(s)					
tDCSG	9.79 ± 2.17	8.64 ± 1.69*	0.717	7.020	.011
CG	10.06 ± 2.60	9.73 ± 2.47			

Mean ± SD (10MWT: 10 meter walk test, 5STST = 5-repetition sit-to-stand test).
The significance levels were evaluated using the repeated ANOVA. Between-group differences at measurement independent *t* test.
CG = control group, tDCSG = tDCS group.
* P < .05.

Table 3

Changes in balance before and after the treatment (N = 57).

			Interaction (Group X Time)		
Group	Pre-exercise	Post-exercise	Effect size d	*F*	*P*
OLSR, s					
tDCSG	12.98 ± 1.41	13.85 ± 1.87	0.172	0.403	.528
CG	13.31 ± 1.84	13.86 ± 2.47			
OLSL, s					
tDCSG	13.28 ± 1.31	14.32 ± 2.36*	0.666	6.043	.017
CG	13.92 ± 1.93	13.66 ± 2.22			
TUG, s					
tDCSG	8.73 ± 1.83	8.18 ± 1.39	0.219	0.654	.422
CG	8.68 ± 1.77	8.28 ± 1.74			

Mean ± SD.
The significance levels were evaluated using the repeated ANOVA. Between-group differences at measurement independent *t* test.
CG = control group, OLSL = One-leg standing left, OLSR = One-leg standing right, tDCSG = tDCS group, TUG = Timed up and go test.
* P < .05.

dizziness was reduced. During the course of the exercise, subjects initially complained of dizziness multiple times, even although the repetition number of exercises was low during exercises performed for 30 minutes. However, in subsequent rehabilitation sessions, the symptoms of dizziness decreased, which led to the increased in performance frequency. This rehabilitation process is seen as a result of the reinforcement of adaptation.

Halmagyi et al[29] reported that permanent loss of balance experienced by some patients after acute vestibular neuritis was due to compensation of inappropriate central nerves, incomplete peripheral recovery, and vestibular rehabilitation. However, Rossi-Izquierdo et al[30] found that vestibular rehabilitation was effective and safe for unstable patients, but there was no enough evidence to distinguish the effects of the different treatment regimens. Therefore, computerized dynamic posturography exercise was applied to the patients with chronic unilateral peripheral vestibular disorders. They were divided into one group with an intervention frequency of 10 and another group with an intervention frequency of 5. As a result, the limits of stability were improved in the group with the intervention frequency of 10. In addition, the group with the intervention frequency of 5 showed improved results, suggesting the need for 5 times more of intervention of vestibular rehabilitation in patients with peripheral vestibular disorder. In this study, the experimental groups performed the VRE with SRT 12 times and showed a significant improvement in balance ability after the exercise. The disequilibrium has no symptoms when the patient was lying or sitting down. However, when standing or walking, it is not centered, it collapses or staggers, and appears when there is an abnormality in motor control, such as vestibular spinal reflex, proprioception, and cerebellum.[31] The exercise method of this study recommends starting the VRE at the supine position, as this position has less symptoms of balance disorders. The disequilibrium was adapted through a postural change to the sitting position and then to the standing position, which gradually showed a balance disorder. In addition, the SRT, which is used to improve posture stability, is believed to improve the subject's balance ability by inducing alternation or co-contraction of the agonist and antagonist muscles during the postural change process.[19] In addition, the recovery of vestibular dysfunction has a function of substituting the body with other functions such as visual and somatosensory functions, thereby replacing the degraded vestibular function. In this study, it was considered that the balance ability was improved by improvement of visual and somatosensory functions through the application of head and eyeball exercises and alternate stimulation of the agonist and antagonist muscles by SRT. The application of SRT and VRE to patients with vestibular neuritis improved balance ability. On the basis of these results, SRT with the VRE program will more effectively improve the balance ability of elderly or nervous system patients with a balance disorder.

The limitation of this study was that it was difficult to gather subjects with vestibular neuritis, because of its low incidence rate compared with other diseases, which made it difficult for us to compare experimental and control groups. Therefore, the actual effect was not confirmed between the experimental and control groups. Exercise was performed only over a 4-week period with no follow-up. We believe that more detailed analysis of the age groups, the onset of symptoms, gender, weather, and other factors related to patients with vestibular neuritis will provide more meaningful information. Future studies should complement this limitation.

5. Conclusion

The VRE program with SRT was effective in reducing dizziness and improving the balance ability of patients with vestibular neuritis.

Author contributions

Conceptualization: Beomryong Kim, JongEun Yim.
Data curation: Beomryong Kim.
Formal analysis: Beomryong Kim, Everett Lohman, JongEun Yim.
Investigation: Beomryong Kim.
Methodology: Jongeun Yim.
Supervision: Everett Lohman, JongEun Yim.
Writing – original draft: Beomryong Kim.
Writing – review & editing: Everett Lohman, JongEun Yim.

References

[1] Fishman JM, Burgess C, Waddell A. Corticosteroids for the treatment of idiopathic acute vestibular dysfunction (vestibular neuritis). Cochrane Database Syst Rev 2011;11:CD008607.
[2] Adamec I, Skorić MK, Handžić J, et al. Incidence, seasonality and comorbidity in vestibular neuritis. Neurol Sci 2015;36:91–5.
[3] Choi KD, Goh EK. Vestibular neuritis and bilateral vestibulopathy. J Korean Med Assoc 2008;51:992–1006.
[4] Yilmaz-Kusbeci O, Aktepe OC, Miman O, et al. Serum viral and toxoplasma gondii antibody titers in vestibular neuronitis. J Int Adv Otol 2010;6:342–6.
[5] Kim J, Lopez I, DiPatre P, et al. Internal auditory artery infarction clinicopathologic correlation. Neurology 1999;52:40–140.
[6] Choi KD, Oh SY, Kim HJ, et al. Recovery of vestibular imbalances after vestibular neuritis. Laryngoscope 2007;117:1307–12.
[7] Lim HW, Chae SW. Evaluation and treatment of the patient with acute dizziness in primary care. J Korean Med Assoc 2010;53: 898–910.
[8] Baloh RW, Kerber K. Baloh and Honrubia's clinical neurophysiology of the vestibular system. Oxford: Oxford University Press; 2011.
[9] Curthoys IS. The interpretation of clinical tests of peripheral vestibular function. Laryngoscope 2012;122:1342–52.
[10] Lin CM, Young YH. Identifying the affected branches of vestibular nerve in vestibular neuritis. Acta Otolaryngol 2011;131:921–8.
[11] Fife T, Tusa R, Furman J, et al. Assessment: vestibular testing techniques in adults and children: report of the therapeutics and technology assessment subcommittee of the American academy of neurology. Neurology 2000;55:1431–41.
[12] Rambold H. Clinical value of rotational-chair testing in vestibular disease. Clin Otorhinolaryngol 2017;1:13.
[13] Hain TC, Cherchi M, Yacovino DA. Bilateral vestibular weakness. Front Neurol 2018;9:344.
[14] Han BI, Song HS, Kim JS. Vestibular rehabilitation therapy: review of indications, mechanisms, and key exercises. J Clin Neurol 2011;7: 184–96.
[15] Zee DS, Jareonsettasin P, Leigh R. Ocular stability and set-point adaptation. Philos Trans R Soc Lond B Biol Sci 2017;372:20160199.
[16] Cawthorne T. The physiological basis for head exercises. J Char Soc Physiother 1944;3:106–7.
[17] Cooksey F. Rehabilitation in vestibular injuries. Proc R Soc Med 1946;39:273–8.
[18] Kisner C, Colby LA, Borstad J. Therapeutic exercise: foundations and techniques. Fa Davis 2017;32:176.
[19] Adler SS, Beckers D, Buck M. PNF in practice: an illustrated guide. Springer 2007.
[20] Jung DK, Chung Y. The effect of hip joint strengthening exercise using proprioceptive neuromuscular facilitation on balance, sit to stand and walking ability in a person with traumatic brain injury: a case report. Phys Ther Rehabil Sci 2017;6:96–104.
[21] Cayco CS, Gorgon EJR, Lazaro RT. Effects of proprioceptive neuromuscular facilitation on balance, strength, and mobility of an older adult with chronic stroke: a case report. J Bodyw Mov Ther 2017;21:767–74.

[22] Jacobson GP, Newman CW. The development of the dizziness handicap inventory. Arch Otolaryngol Head Neck Surg 1990;116: 424–7.
[23] Lingjærde O, Føreland AR. Direct assessment of improvement in winter depression with a visual analogue scale: high reliability and validity. Psychiatry Res 1998;81:387–92.
[24] Berg KO, Wood-Dauphinee SL, Williams JI, et al. Measuring balance in the elderly: validation of an instrument. Can J Public Health 1992;83:S7–11.
[25] Blum L, Korner-Bitensky N. Usefulness of the Berg Balance Scale in stroke rehabilitation: a systematic review. Phys Ther 2008;88:559–66.
[26] Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991; 39:142–8.
[27] Sparrer I, Duong Dinh TA, Ilgner J, et al. Vestibular rehabilitation using the Nintendo(Wii Balance Board–a user-friendly alternative for central nervous compensation. Acta Otolaryngol 2013;133:239–45.
[28] Crane BT, Schubert MC. An adaptive vestibular rehabilitation technique. Laryngoscope 2018;128:713–8.
[29] Halmagyi G, Weber K, Curthoys I. Vestibular function after acute vestibular neuritis. Restor Neurol Neurosci 2010;28:37–46.
[30] Rossi-Izquierdo M, Santos-Pérez S, Rubio-Rodríguez J, et al. What is the optimal number of treatment sessions of vestibular rehabilitation? Eur Arch Otorhinolaryngol 2014;271:275–80.
[31] Nishi T, Kamogashira T, Fujimoto C, et al. Effects of peripheral vestibular dysfunction on dynamic postural stability measured by the functional reach test and timed up and go test. Ann Otol Rhinol Laryngol 2017;126:438–44.