JKPT Vol. 29, No. 6, December 2017
J Kor Phys Ther 2017:29(6):316-323
pISSN 1229-0475 eISSN 2287-156X

Review Article

https://doi.org/10.18857/jkpt.2017.29.6.316

Review on Physical Therapy for Patients with Vestibular Disorder

Yong Hyun Kwon[1], Yu Min Ko[2]

[1]Department of Physical Therapy, Yeungnam University College, Daegu; [2]Department of Physical Therapy, Gangneung Yeungdong College, Gangneung-si, Korea

Effort to improve balance ability in the field of rehabilitation has been constantly issued and developed up to now. A variety of subcomponent of postural control including function and cognition should be needed in many body systems and be complicatedly linked to each system. In South Korea, although decreased postural dysfunction due to neurological or musculoskeletal disorders has been well documented, we do not have many experience and knowledge of vestibular rehabilitation for maintain and improve balance function. In the United States, vestibular physical therapy is already acknowledged as clinical subspecialty by American Physical Therapy Association. However, there is no curriculum subject related to vestibular rehabilitation in standard education of physical therapy and no specialist who has clinical experience and knowledge of this realm. Therefore, we reviewed general information and basic knowledge of vestibular rehabilitation such as current state of vestibular disorder in South Korea, pathology, major causes of vestibular dysfunction including peripheral vestibular disorders, vestibular neuritis, benign paroxysmal positional vertigo, and central disorder, evaluation of vestibular dysfunction, and treatment for vestibular dysfunction new approaches. We expect that physical therapist in South Korea recognize clinical significance of vestibular exercise and that clinical concern and research will be begun in near future.

Keywords: Dizziness, Balance, Vestibular exercise, Vestibular disorders

INTRODUCTION

Physical therapy intervention attempts to facilitate and perform functional activities in a daily lives by treating physical impairment due to injury of musculoskeletal, cardiopulmonary, central and peripheral nerve system, and so forth. According to specialty sections of physical therapy in American Physical Therapy Association, physical therapy is divided into many sub-specialty of clinical and academic fields, such as neurology, orthopedics, pediatrics, geriatrics, sports, oncology, cardiovascular & pulmonary, etc. In South Korea, major clinical areas consist of neurological, musculoskeletal, and pediatric physical therapy. Recently, a few areas among specialty area in the United State such as cardiovascular & pulmonary, oncology, geriatrics are newly interested in our clinical setting. In the United State, vestibular rehabilitation become a newly interested specialty in clinical professions, which belong to sub-section of neurology in American Physical Therapy Association. Many physical therapy area attempt to acquire vestibular concept in their exercise program to improve balance performance for their patients. However, view of our clinical interest area is still narrow and small especially in vestibular rehabilitation, comparing with one of the United State. There is no academic journal and society in South Korea, and of course, no many researches have not been published. However, many patients with vestibular dysfunction or with falling risk demand adequate physical therapy evaluation and treatment to alleviate their sufferings. Therefore, we tried to introduce a general outline of this field to raise clinical and academic interest of vestibular physical therapy in our country.

Vestibular dysfunction & rehabilitation

Vestibular dysfunction is commonly featured by vertigo, dizziness, visual and gaze balance disturbance, and imbalance.[1] The dysfunction is caused by a disease-related pathology in brain and vestibular

Received Dec 4, 2017 **Revised** Dec 24, 2017
Accepted Dec 28, 2017
Corresponding author Yu Min Ko
E-mail koyumin@hanmail.net

structures.[2] Dizziness and vertigo are the most common complaints in patient with vestibular dysfunction and older population.[3] Dizziness is defined as an impairment in spatial perception and visual/postural stability, accompanying a non-specific feeling such as a giddy or rotational sensation, a loss of balance, a faint feeling, lightheadedness, instability or unsteadiness, a tendency to fall, or a feeling of everything turning black.[4] Vertigo, the most common type of dizziness, is a medical condition that patient have a sense of rotation and spinning of their visual environment as if the objects around them are spinning.[5] Many unpleasant symptoms such as nausea, vomiting, sweating, imbalance, etc may be provoked.

Dizziness is one of the most prevalent complaint among adults aged in 60 seconds and older.[2] According to Sloan et al.,[4] adults older than 60 years had one or more experience of a significant dizziness in a year on average which followed by a medical evaluation, intervention with a medication. Moreover, they reported that proportion of severe symptom affected by physical activities within past year was 20%. It is well known that dizziness and vertigo strongly deteriorates a daily activities of life especially in older people and that they have high potential risk of falling. Falling in the elderly lead to impair severe musculoskeletal structures related to physical function, which increases national health care budget. Vestibular dysfunction significant deteriorates confidence of balance ability leading to increase falling risk.[6] Therefore, it is a general consesis that vestibular rehabilitation reduces burden related fall injuries and improve life quality in patients with vestibular dysfunction.[7,8]

Vestibular rehabilitation is a wide frame of concept to imply establishment of compensatory strategy followed by vestibular disease and of therapeutic strategy like postural training and adaptation in other symptoms of vertigo, dizziness, or general unsteadiness.[9] It implies a comprehensive clinical fields including direct rehabilitation intervention for main vestibular disorder as well as adaptation approach of central nerve process and compensation of sensory loss or mismatch. Its significance and necessity of vestibular rehabilitation should not be devalued, because of social expense caused by falling in the elderly is continuously increased.[9,10] According to Sweden research,11 the annual direct cost from falls reached almost € 500 million and one from deterioration of life quality amounted to € 500 million. Moreover, these costs are calculated up to about € 2.2 billion by 2050 if the present increasing rate is not changed.[11]

Current state of dizziness and rehabilitation in South Korea

In South Korea, vestibular rehabilitation has been introduced since 1990s, which has begun to be generalized in many clinical settings after 2000s.[12] Several reports showed that patients with dizziness has gradually increased until now.[12,13] In particular, number of patients with vestibular dysfunction reached 850,000, which mean 54% of increment from five years earlier(Previous studies reported that the prevalence of dizziness for 1 year ranged from 6.1% to 27%.[14,15] The prevalence or vestibular dysfunction has shown 35.4% in a cross-sectional study[16] and its variability has been somewhat wide such as 3.1-4.9% for 1 year.[17,18] In South Korea, Koo et al. revealed that the prevalence of dizziness and vestibular dysfunction were 16.7% and 1.84%, respectively.[13] They suggested that dizziness was related with aging, gender, hearing loss, and emotional stress, and that vestibular dysfunction was associated with aging, dizziness experience, and hearing loss.

According to Kim et al.'s study in 2015,[19] statistic data from national insurance health service of Korea showed that patients who visited hospital with complaint of dizziness had been increased up to 19.9% for last 4 years. Several studies indicated that 21% of adults had transient experience of dizziness, and moreover dizziness including complaint of vertigo might arise the prevalence of vestibular dysfunction.[20] For patients with vestibular dysfunction, physical therapist plays important role of treating their medical condition in the United State. However, there have been no interest, education, and medical law that Korean physical therapist could treat and manage vestibular dysfunction. Practically, treatment and education of vestibular rehabilitation has been carried out by other medical professions such as medical doctor, nurse, or audiologist.[21]

Major causes of vestibular dysfunction

1. Peripheral vestibular disorders

Peripheral vestibular disorders are one of the most common vestibular dysfunction in older adults and very prevalent in them with a fall history.[22] It is caused by unilateral or bilateral injury of the peripheral vestibular system. Patients with peripheral vestibular disorders, which are classified into four types, in terms of unilateral or bilateral vestibular loss, benign paroxysmal positional vertigo (BPPV), vestibular neuritis, and Meniere's syndrome usually com-

plaints vertigo.[23,24] Dizziness including vertigo is common implication for physical therapy intervention. It was well known that vestibular rehabilitation had significant better outcomes in patients with rehabilitative intervention, compared with patients in control groups.[25,26] A recent Cochrane review showed that vestibular rehabilitation had the effectiveness in the recovery of unilateral peripheral vestibular disorders.[25] For example, Marioni et al. reported that home-based vestibular rehabilitation exercise using a posturography-assisted device was effective approach for individuals with acute unilateral peripheral vestibular disorder than persons without intervention in a wait-list.[27] According to converging evidences, the recovery of bilateral vestibular disorder is more challenging than bilateral disorder in dynamic balance and postural stability.[28]

Vestibular neuritis is a typical cause of unilateral peripheral vestibular disorders and its incidence is estimated as 3.5 per 100,000 in the public.[29,30] Patients with vestibular neuritis usually have experience of vertigo and balance problem accompanying with nausea, vomiting, and horizontal-torsional nystagmus toward the lesion side.[23,29] In addition, they have a positive sing on head impulse test, unilateral caloric test, or decrease of vestibular evoked myogenic potential.[31] Traditionally steroids are commonly used to improve their symptoms in the acute stage of vestibular neuritis, which lead to improve function of vestibular system and quality of daily life. However, as results of current converging studies, clinical effectiveness of the medicine is still controversial.[24,32]

Interestingly, vestibular rehabilitation for acute patients with vestibular neuritis could have equivalent effect in the clinical, canal, and otolith outcome assessments, compared with administration of corticosteroids.[33] Its exercise protocol comprised horizontal-vertical movements of the head as well as training of gait and balance to improve gaze control and posture stability of gaze. The effectiveness of vestibular therapy might be explained as central compensation that need the use of one or more of three vestibular mechanism in terms of the vestibular ocular reflex (VOR), habituation, and substitution.[34-36] Prior study suggested that patients with vestibular neuritis who reach functional recovery through vestibular rehabilitation showed structural changes of certain area of the brain.[35] Early vestibular rehabilitation seem to be important factor in facilitating central compensation and improving vestibular symptoms.[36]

Benign paroxysmal positional vertigo (BPPV) is one of the most common causes of vertigo by a problem in the inner ear. Major symptom is repeated and short period of vertigo that feels a spinning sensation, accompanied by head movement upon change in the position of the head. BPPV is common disorder of vestibular system in the elderly.[37] According to the German National Telephone Health Interview Survey,[37] the incidence of BPPV was 2.4% of prevalence in a lifetime, and the 1-year prevalence and the 1-year incidence was 1.6% and 0.6% respectively. In addition, they suggested that 86% of people with BPPV make a complaint of medical consultation, lost time at their work, or functional change.

Symptom onset of BPPV is typically provoked with a change of head position with regard to gravity, and the duration commonly lasts about 1 min, with an occasionally delayed onset.[38] For initial evaluation for BPPV, frequency, duration, and description of symptoms and fatigability should be taken when vertigo or dizziness occurs. For arising diagnostic accuracy, cautious assessment of subjective complaint is extracted from patients with BPPV.

Major clinical tests are the Dix-Hallpike teat or the roll test. The dix-Hallpike test is used to assess the involvement of the posterior semicircular canal, which cause vertigo and nystagmus characterized by posterior canal BPPV. Involvement of the horizontal semicircular canal is determined by the roll test. Both the Dix-Hallpike and roll test induce the signs and symptoms in patients with BPPV.

Several prior studies suggested that BPPV may be related with osteoporosis and migraine.[39-42] 56% of patients with BPPV recurrence within 1 year had a diagnosis of osteoporosis, comparing with 16% of BPPV recurrence in those with normal bone density. However, Yu et al. addressed that older women with osteoporosis might be related with BPPV but that there is no strong relationship.[43] Still it is controversial. For migraine, Faralli et al. indicated that BPPV with migraine was observed in younger people than those with BPPV without history of migraine.[44] BPPV patients with migraine commonly showed more disabled symptoms.[44] In addition, a recurrence of BPPV was reported as 15.5% to 17% rate, and it seemed to be showed in the elderly than younger people with BPPV.[43,45]

2. Central vestibular disorder

Recently, there are converging evidences, suggesting that patients with central disorder such as concussion, stroke, and vestibular migraine can be improved by vestibular rehabilitation.[46-51] Schneider et al. reported that combined treatment with vestibular and cervical exercises reduce the to return to sport activity in people with symptoms of headaches and dizziness after concussion. For a trial of screen for sport-related concussion, the vestibular/ocular motor screening test was recently introduced, which consisted of vertical and horizontal saccades, smooth pursuit, the horizontal VOR, and

https://doi.org/10.18857/jkpt.2017.29.6.316

close point of convergence distance.[51] The test seems to sensitively and simply screen vestibular and ocular motor function after sport related concussion.

Strokes with the injury of the brain stem due to vascular abnormality of posterior circulation commonly showed central vestibular dysfunction characterized by vertigo and balance problem.[52] Several studies revealed that a customized physical therapy intervention for stroke patients with brainstem injury who had vestibular symptoms identified significant improvement in postural control and functional activities.[53,54] In addition, vestibular exercise program improved neglect symptom and activities of daily live in patients with stroke.[55]

Evaluation of vestibular dysfunction

The dizziness handicap inventory (DHI) determines how the level of impairment is affected in a patient with dizziness. The DHI is a reliable and standardized 25 questionnaire that manifests the patient's perceived disability from dizziness. It is divided into three categories in terms of emotional, physical, and functional impacts of dizziness on daily life.[56] DHI indicated clinical symptom change over time in patients with peripheral and central vestibular dysfunction.[57] The vertigo handicap questionnaire (VHQ) is developed to assess the disabling consequences of vertigo on quality of life.[58] It comprises 22-item questionnaires four categories of effects of vertigo in terms of activity, social anxieties, fear of vertigo, and severity of episodes. The vestibular disorders activities of daily living scale (VADL) is self-rated scales with 28 items to determine level of functional limitation or disability in individuals with vestibular dysfunction. The scale is categorized into three division; basic self-performed independent tasks, mobility skills, and higher-level or complex tasks outside the home.[58] These three scales have slightly different aspects.[59] The DHI and VHQ are designed to assess specific symptoms. However, the DHI focused on the dysfunction of dizziness related quality of life, whereas the VHQ assesses the impact of vertigo in daily functional activities, and the VADL measures the functional limitations of daily life activities.[58] The activities-specific balance confidence (ABC) scale is useful for measuring balance confidence in the elderly and people with vestibular dysfunction.[60] The scale is rated from 0% to 100%, with 100% representing the best balance confidence through performing 16 different balance tasks. 67% or less scores have indicated the increase of fall risk in older population.[61]

Besides specific scales for vertigo and dizziness, there are several balance tests and clinical tools in the realm of rehabilitation. Static and dynamic balance tests are usually used to figure out the current balance ability or improve postural control.[2] For test of static balance, the modified clinical test of sensory integration and balance (CTSIB) with four condition (eyes open/closed and firm/flexible surface) is specially measured to quantify change of postural sway for up to 30 seconds.[62,63] For test of dynamic balance, computerized dynamic posturography is used to quantitatively record postural sway in individuals with vestibular dysfunction.[64,65] As traditionally-clinical tests, there are the timed up and go (TUG) test, the dynamic gait index (DGI), and the functional gait assessment (FGA).[66,67] These tests are assessed to demonstrate change of gait or balance improvement in patients. In particular, the DGI and FGA are focused on movement of the head during walking with specific activities requiring higher-level function such as backward gait, step up and down stairs, turning around, and gait with eyes closed. Physical therapist need to additionally examine routine clinical assessment such as muscle strength, range of motion, sensory, function of cranial nerve, etc. Moreover, several assessments for eye movement should be examined in terms of saccades, VOR cancellation, vergence, the head thrust test, gaze-evoked nystagmus, and smooth pursuits.[2]

Treatment for vestibular dysfunction

1. General vestibular therapies

Vestibular physical therapy is a therapeutic program aimed to improve patient's ability of postural control by training sensory substitution as well as to adapt the vestibulocular reflex (VOR) such as change of the VOR gain and movement habituation.[68] Particularly in patients with peripheral vestibular dysfunction, physical therapist generally tried to have their patient adapt the errant perception of vestibular signal from the affected ear structure and change the gain of VOR using specific combination of eye and head movements.[69] The VOR adaptation that has been well defined is used as the first treatment method in physical therapist to reduce dizziness symptoms.[2,70] Habituation is a form of learning in which learner decreases its responses to repetitive stimulus. Physical therapist provides a provoking stimulus repetitively with patients who have the dizziness in order to cease or decrease their exaggerated symptoms.[71] Sensory substitution is applied to improve release of vestibular symptoms and comprehensive balance function by using substitutive intact sensation instead of loss of vestibular sensory inputs.

2. Methods of vestibular exercise

On the whole, therapeutic intervention for vestibular rehabilitation comprises static and dynamic exercise focused on stability of gaze and gait.[36] There are three main vestibular exercise used for rehabilitation settings in terms of vestibulo-ocular reflex stimulation exercise, substitution exercise, and habituation exercise. VOR stimulation exercise is categorized as adaptation exercise. It is used for improvement of the VOR gain that required to stabilize gaze and visual focus during head movement. VOR exercise is usually designed to gradually modulate its difficulty by increasing the speed of head movement or a target. In addition, the exercise can be upgraded by moving a target in opposite direction of head motion, which lead to the double amplitude of gaze control ability needed for vision fixation on a target.[36] As patients' performance is improved, variability of the exercise should be modified at different levels of distance and speed of a target as well as various position.[72]

Substitution exercises is used to strengthen the visual and somatosensory inputs by challenging balance activity in various condition such as with disturbed vision, with the eyes closed, or on unstable surfaces. These balance activities enhance adjustment of vestibular and proprioceptive input.[36] Substitution exercise should be advanced to more challenging condition from the eyes opened to the eyes closed or from on a firm surface to on a compliant surface. In addition, the exercise can be performed during various dual activities.

Habituation exercise is used to enhance the thresholds of the clinical symptom by repetition of the provocative motion or stimulus.[36] Over time human brain get adapted to the repetitive abnormal input and stimulus causing dizziness symptom. Habituation exercise focuses on vestibular rehabilitation for patients with BPPV in terms of the Epley's or Semont's maneuvers used for particle repositioning.[36] These positional techniques are well known to alleviate symptoms of dizziness.[36] It was reported that specific exercise focused on vestibular adaptation using repetitive head motion for habituation of vestibular response could improve balance ability and gait performance in patients treated with positional maneuvers.[73]

3. New approaches

Recently, a variety of approaches has newly developed in vestibular rehabilitation, in terms of dual task, virtual reality, tai chi, electrical stimulation, aquatic therapy etc.[36] Dual task requiring competition of attention components is a successful achievement of performing postural control and cognitive demand at the same time. Attentional ability in the elderly causes to increase falling risks.[74,75] According to Bernard-Demanze's study,[76] there was difference between younger and older adults in strategy of postural control with dual task. They reported that dual task led to increase their postural ability in younger people, whereas not in the elderly. This results implied that postural control was automated by attentional shift from balance task to cognitive demanded task in younger adults. However, it was difficult for the elderly to prioritize and select postural strategy between dual task comprising postural control and cognitive task. Therefore, types and difficult levels of dual task should be used appropriately depending on subject's age and postural ability.

Virtual reality is one of recent advanced approaches in vestibular rehabilitation that lead to improve postural control and dizziness symptom.[72] NASA has used virtual reality for training the vestibular function to reduce motion sickness, to increase orientation of verticality, and to facilitate recovery when return to environment with normal gravity.[77] Palvlou and coll reported that intervention using dynamic virtual environments is valuable to vestibular rehabilitation for patients with peripheral vestibular dysfunction.[78]

Electrical stimulation using galvanic direct current is a useful approach adjunct to vestibular rehabilitation for the treatment of patients with bilateral or unilateral vestibular loss.[79,80] Tai chi is an effective exercise for patients or the elderly without good balance performance by decreasing fall risk.[81] Slow and well controlled movement might facilitate the algorism of balance system in complementary way, compared with conventional training such as head movement exercise, standing, and walking.[36] In addition, Gabilan et al. revealed that patients with chronic dizziness with unilateral vestibular hypofunction showed improvement of postural control and dizziness through aquatic physical therapy adjunct to vestibular rehabilitation including various tasks in a pool and balance control in turbulence environment.[82]

Discussion

It is evident that vestibular physical therapy is effective intervention for patients with postural dysfunction according to previous studies suggesting that vestibular exercise improved symptoms of vertigo and dizziness, postural control, and life quality.[2,34,83] Moreover, there is strong evidence that vestibular therapy is beneficial and safe intervention for patients with peripheral vestibular dysfunction or dizziness symptoms.[83] Vestibular rehabilitation is cost effective and use-

https://doi.org/10.18857/jkpt.2017.29.6.316

ful in primary care service as well as some emergency care.[83] Vestibular dysfunction is highly associated with fall, which can lead to serious problem in the elderly.[16,84] Physical therapist should modify patients' behavior if they complain of recent falling experience, and evaluate their balance deficits.[2]

As for evaluation of vestibular dysfunction, prolonged subjective symptoms and suspicious compensative behavior should be detected before development of chronic state. In addition, there are a variety of dizziness-like symptoms not related to vestibular dysfunction in terms of Functional dizziness, persistent postural-dizziness, phobic postural vertigo, and chronic subjective dizziness due to anxiety and depression.[9] So, clinicians should make certain that patients with one of these overlapping syndromes complain of incorrect sensory interpretation, because these factors disrupt physical therapy intervention.[85] Although patients might be expected to have promising short-term recovery, many cases showed less convincing long-term result.[86] Prior studies showed that anxiolytic and antidepressant drugs could have profitable effects on vestibular symptoms, even if vestibular dysfunction would be the original cause.[86] Besides these factors to affect dizziness, muscular pain/tension and distorted spatial orientation resulted in deterioration of postural control, which is high related to motion sensitivity observed in patients with dizziness.[60,61,87]

Challenging movement over already-retained balance ability is important factor to improve function in patients with vestibular disorders. Previous studies suggested that vestibular therapy should get started early after the onset and be tailored appropriately to individual's functional ability in sensory, motor, and cognitive system.[88] On the other hand, there are some negative factors to affect recovery in terms of migraines, abnormal sensory and cognition, visual comorbidities, sensitivity to motion, psychologic condition, and neurologic pathology.[89] Although the complaint of symptoms and physical limitation including laboratory findings is very diverse among patients, common symptoms are generally defined such as unstable walking, increased falling risk, blurring vision during head motion, and so forth.[89]

As electrical engineering has been recently developed, new devices are introduced such as smart-phone applications for vestibular exercise, home or institutional based exercise program using virtual reality.[90,91] Development of robotic assisted gait training will help patients with balance problem due to vestibular dysfunction for recovery their functional ability and self confidence.[92] Moreover, vestibular implants invented to recover the loss of vestibular function was proved to be safe and effective.[93] In summary, Korean physical therapy society need to have attention on pathology, evaluation, and treatment of vestibular dysfunction. With the elderly sharply increased, our health care systems will focus on preventing falls or treating patient with dizziness or vertigo. Unfortunately, there are few specialists who take clinical experience and scientific knowledge in our rehabilitation settings. In the future. I suggest that professional education of vestibular physical therapy should be established as standard education. In addition, vestibular exercise for balance deficit and fall risk can be modified and used for any other patients without normal function due to neurological or musculoskeletal disorders.

REFERENCES

1. Furman JM CS, Whitney SL. Vestibular disorders a case study approach. New York, Oxford University Press, 2010.
2. Hillier S, McDonnell M. Is vestibular rehabilitation effective in improving dizziness and function after unilateral peripheral vestibular hypofunction? An abridged version of a Cochrane review. Eur J Phys Rehabil Med. 2016;52(4):541-56.
3. Neuhauser HK, von Brevern M, Radtke A et al. Epidemiology of vestibular vertigo: a neurotologic survey of the general population. Neurology. 2005;65(6):898-904.
4. Sloane PD, Coeytaux RR, Beck RS et al. Dizziness: state of the science. Ann Intern Med. 2001;134(9 Pt 2):823-32.
5. Post RE, Dickerson LM. Dizziness: a diagnostic approach. Am Fam Physician. 2010;82(4):361-8.
6. Whitney SL, Hudak MT, Marchetti GF. The dynamic gait index relates to self-reported fall history in individuals with vestibular dysfunction. J Vestib Res. 2000;10(2):99-105.
7. Gamiz MJ, Lopez-Escamez JA. Health-related quality of life in patients over sixty years old with benign paroxysmal positional vertigo. Gerontology. 2004;50(2):82-6.
8. Pavlou M. The use of optokinetic stimulation in vestibular rehabilitation. J Neurol Phys Ther. 2010;34(2):105-10.
9. Tjernstrom F, Zur O, Jahn K. Current concepts and future approaches to vestibular rehabilitation. J Neurol. 2016;263 Suppl 1:S65-70.
10. Gillespie LD, Robertson MC, Gillespie WJ et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2012(9):CD007146.
11. Gyllensvard H. Cost-effectiveness of injury prevention - a systematic review of municipality based interventions. Cost Eff Resour Alloc. 2010; 8:17.
12. Rhee CK. Vestibular rehabilitation. Audiol Speech Res. 2010;6(1):1-9.
13. Koo JW, Chang MY, Woo SY et al. Prevalence of vestibular dysfunction and associated factors in South Korea. BMJ Open. 2015;5(10):e008224.
14. Mueller M, Strobl R, Jahn K et al. Burden of disability attributable to vertigo and dizziness in the aged: results from the KORA-age study. Eur J Public Health. 2014;24(5):802-7.
15. Nakashima K, Yokoyama Y, Shimoyama R et al. Prevalence of neurological disorders in a Japanese town. Neuroepidemiology. 1996;15(4):208-13.

16. Agrawal Y, Carey JP, Della Santina CC et al. Disorders of balance and vestibular function in us adults: data from the National Health and Nutrition Examination Survey, 2001-2004. Arch Intern Med. 2009;169(10): 938-44.
17. Neuhauser HK, Radtke A, von Brevern M et al. Burden of dizziness and vertigo in the community. Arch Intern Med. 2008;168(19):2118-24.
18. Lai YT, Wang TC, Chuang LJ et al. Epidemiology of vertigo: a national survey. Otolaryngol Head Neck Surg. 2011;145(1):110-6.
19. Kim JY, Jeong SY, Park SM et al. Oriental medical treatment pattern of Korean patients with dizziness or vertigo. J Orient Neuropsychiatry. 2015;26(3):225-34.
20. Neuhauser HK. Epidemiology of vertigo. Curr Opin Neurol. 2007;20(1): 40-6.
21. Lee HJ, Choi SM. Factors influencing adherence to vestibular rehabilitation exercise program in patients with dizziness. Korean J Adult Nurs. 2014;26(4):434-43.
22. Liston MB, Bamiou DE, Martin F et al. Peripheral vestibular dysfunction is prevalent in older adults experiencing multiple non-syncopal falls versus age-matched non-fallers: a pilot study. Age Ageing. 2014;43:38-43.
23. Smouha E. Inner ear disorders. NeuroRehabilitation. 2013;32(3):455-62.
24. Strupp M, Brandt T. Peripheral vestibular disorders. Curr Opin Neurol. 2013;26(1):81-9.
25. Hillier SL, McDonnell M. Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. Cochrane Database Syst Rev. 2011(2): CD005397.
26. Alghadir AH, Iqbal ZA, Whitney SL. An update on vestibular physical therapy. J Chin Med Assoc. 2013;76(1):1-8.
27. Marioni G, Fermo S, Lionello M et al. Vestibular rehabilitation in elderly patients with central vestibular dysfunction: a prospective, randomized pilot study. Age (Dordr). 2013;35(6):2315-27.
28. Ogata Y, Sekitani T, Shimogori H et al. Bilateral vestibular neuronitis. Acta Otolaryngol Suppl. 1993;503:57-60.
29. Reinhard A, Maire R. [Vestibular neuritis: treatment and prognosis]. Rev Med Suisse. 2013;9(400):1775-9.
30. Sekitani T, Imate Y, Noguchi T et al. Vestibular neuronitis: epidemiological survey by questionnaire in Japan. Acta Otolaryngol Suppl. 1993;503: 9-12.
31. Jeong SH, Kim HJ, Kim JS. Vestibular neuritis. Semin Neurol. 2013; 33(3):185-94.
32. Fishman JM, Burgess C, Waddell A. Corticosteroids for the treatment of idiopathic acute vestibular dysfunction (vestibular neuritis). Cochrane Database Syst Rev. 2011;(5):CD008607.
33. Goudakos JK, Markou KD, Psillas G et al. Corticosteroids and vestibular exercises in vestibular neuritis. Single-blind randomized clinical trial. JAMA Otolaryngol Head Neck Surg. 2014;140(5):434-40.
34. Herdman SJ. Vestibular rehabilitation. Curr Opin Neurol. 2013;26(1):96-101.
35. Hong SK, Kim JH, Kim HJ et al. Changes in the gray matter volume during compensation after vestibular neuritis: a longitudinal vbm study. Restor Neurol Neurosci. 2014;32(5):663-73.
36. Deveze A, Bernard-Demanze L, Xavier F et al. Vestibular compensation and vestibular rehabilitation. Current concepts and new trends. Neurophysiol Clin. 2014;44(1):49-57.
37. von Brevern M, Radtke A, Lezius F et al. Epidemiology of benign paroxysmal positional vertigo: a population based study. J Neurol Neurosurg Psychiatry. 2007;78(7):710-5.
38. Bhattacharyya N, Baugh RF, Orvidas L et al. Clinical practice guideline: Benign paroxysmal positional vertigo. Otolaryngol Head Neck Surg. 2008;139(5 Suppl 4):S47-81.
39. Kim HA, Lee H. Autonomic dysfunction as a possible cause of residual dizziness after successful treatment in benign paroxysmal positional vertigo. Clin Neurophysiol. 2014;125(3):608-14.
40. Yamanaka T, Shirota S, Sawai Y et al. Osteoporosis as a risk factor for the recurrence of benign paroxysmal positional vertigo. Laryngoscope. 2013;123(11):2813-6.
41. Talaat HS, Abuhadied G, Talaat AS et al. Low bone mineral density and vitamin d deficiency in patients with benign positional paroxysmal vertigo. Eur Arch Otorhinolaryngol. 2015;272(9):2249-53.
42. Yu S, Liu F, Cheng Z et al. Association between osteoporosis and benign paroxysmal positional vertigo: a systematic review. BMC Neurol. 2014; 14:110.
43. Prokopakis E, Vlastos IM, Tsagournisakis M et al. Canalith repositioning procedures among 965 patients with benign paroxysmal positional vertigo. Audiol Neurootol. 2013;18(2):83-8.
44. Faralli M, Cipriani L, Del Zompo MR et al. Benign paroxysmal positional vertigo and migraine: analysis of 186 cases. B-ENT. 2014;10(2): 133-9.
45. Babac S, Djeric D, Petrovic-Lazic M et al. Why do treatment failure and recurrences of benign paroxysmal positional vertigo occur? Otol Neurotol. 2014;35(6):1105-10.
46. Diaz DS. Management of athletes with postconcussion syndrome. Semin Speech Lang. 2014;35(3):204-10.
47. Schneider KJ, Meeuwisse WH, Nettel-Aguirre A et al. Cervicovestibular rehabilitation in sport-related concussion: a randomized controlled trial. Br J Sports Med. 2014;48(17):1294-8.
48. Fife TD, Giza C. Posttraumatic vertigo and dizziness. Semin Neurol. 2013;33(3):238-43.
49. Aligene K, Lin E. Vestibular and balance treatment of the concussed athlete. NeuroRehabilitation. 2013;32(3):543-53.
50. Gurley JM, Hujsak BD, Kelly JL. Vestibular rehabilitation following mild traumatic brain injury. NeuroRehabilitation. 2013;32(3):519-28.
51. Mucha A, Collins MW, Elbin RJ et al. A brief vestibular/ocular motor screening (VOMS) assessment to evaluate concussions: preliminary findings. Am J Sports Med. 2014;42(10):2479-86.
52. Whitney SL, Alghwiri A, Alghadir A. Physical therapy for persons with vestibular disorders. Curr Opin Neurol. 2015;28(1):61-8.
53. Kruger E, Teasell R, Salter K et al. The rehabilitation of patients recovering from brainstem strokes: case studies and clinical considerations. Top Stroke Rehabil. 2007;14(5):56-64.
54. Brown KE, Whitney SL, Marchetti GF et al. Physical therapy for central vestibular dysfunction. Arch Phys Med Rehabil. 2006;87(1):76-81.
55. Dai CY, Huang YH, Chou LW et al. Effects of primary caregiver participation in vestibular rehabilitation for unilateral neglect patients with right hemispheric stroke: a randomized controlled trial. Neuropsychiatr Dis Treat. 2013;9:477-84.
56. Jacobson GP, Newman CW. The development of the dizziness handicap inventory. Arch Otolaryngol Head Neck Surg. 1990;116(4):424-7.
57. Jacob RG, Whitney SL, Detweiler-Shostak G et al. Vestibular rehabilita-

https://doi.org/10.18857/jkpt.2017.29.6.316

tion for patients with agoraphobia and vestibular dysfunction: a pilot study. J Anxiety Disord. 2001;15(1-2):131-46.
58. Graziano M. Introduction to the international classification of functioning disability and health - icf - in the context of vestibular rehabilitation. J Vestib Res. 2013;23(6):293-6.
59. Alghwiri AA, Marchetti GF, Whitney SL. Content comparison of self-report measures used in vestibular rehabilitation based on the international classification of functioning, disability and health. Phys Ther. 2011;91(3):346-57.
60. Malmstrom EM, Westergren H, Fransson PA et al. Experimentally induced deep cervical muscle pain distorts head on trunk orientation. Eur J Appl Physiol. 2013;113(10):2487-99.
61. Huntley AH, Srbely JZ, Zettel JL. Experimentally induced central sensitization in the cervical spine evokes postural stiffening strategies in healthy young adults. Gait Posture. 2015;41(2):652-7.
62. Horak FB. Clinical measurement of postural control in adults. Phys Ther. 1987;67(12):1881-5.
63. Wrisley DM, Whitney SL. The effect of foot position on the modified clinical test of sensory interaction and balance. Arch Phys Med Rehabil. 2004;85(2):335-8.
64. Black FO, Angel CR, Pesznecker SC et al. Outcome analysis of individualized vestibular rehabilitation protocols. Am J Otol. 2000;21(4):543-51.
65. Horak FB, Jones-Rycewicz C, Black FO et al. Effects of vestibular rehabilitation on dizziness and imbalance. Otolaryngol Head Neck Surg. 1992;106(2):175-80.
66. Podsiadlo D, Richardson S. The timed "up & go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991;39(2):142-8.
67. Wrisley DM, Marchetti GF, Kuharsky DK et al. Reliability, internal consistency, and validity of data obtained with the functional gait assessment. Phys Ther. 2004;84(10):906-18.
68. Whitney SL, Rossi MM. Efficacy of vestibular rehabilitation. Otolaryngol Clin North Am. 2000;33(3):659-72.
69. Pavlou M, Quinn C, Murray K et al. The effect of repeated visual motion stimuli on visual dependence and postural control in normal subjects. Gait Posture. 2011;33(1):113-8.
70. Whitney SL, Sparto PJ, Hodges LF et al. Responses to a virtual reality grocery store in persons with and without vestibular dysfunction. Cyberpsychol Behav. 2006;9(2):152-6.
71. Vitte E, Semont A, Berthoz A. Repeated optokinetic stimulation in conditions of active standing facilitates recovery from vestibular deficits. Exp Brain Res. 1994;102(1):141-8.
72. Merlingolda V. Vestibular rehabilitation: rehabilitation options for patients with dizziness and imbalance. Nurs J India. 2013;104(1):18-20.
73. Chang WC, Yang YR, Hsu LC et al. Balance improvement in patients with benign paroxysmal positional vertigo. Clin Rehabil. 2008;22(4):338-47.
74. Asai T, Doi T, Hirata S et al. Dual tasking affects lateral trunk control in healthy younger and older adults. Gait Posture. 2013;38(4):830-6.
75. Asai T, Misu S, Doi T et al. Effects of dual-tasking on control of trunk movement during gait: respective effect of manual- and cognitive-task. Gait Posture. 2014;39(1):54-9.
76. Bernard-Demanze L, Dumitrescu M, Jimeno P et al. Age-related changes in posture control are differentially affected by postural and cognitive task complexity. Curr Aging Sci. 2009;2(2):139-49.
77. Stroud KJ, Harm DL, Klaus DM. Preflight virtual reality training as a countermeasure for space motion sickness and disorientation. Aviat Space Environ Med. 2005;76(4):352-6.
78. Pavlou M, Kanegaonkar RG, Swapp D et al. The effect of virtual reality on visual vertigo symptoms in patients with peripheral vestibular dysfunction: a pilot study. J Vestib Res. 2012;22(5-6):273-81.
79. Bittar RS, Barros Cde G. Vestibular rehabilitation with biofeedback in patients with central imbalance. Braz J Otorhinolaryngol. 2011;77(3):356-61.
80. Vuillerme N, Hlavackova P, Franco C et al. Can an electro-tactile vestibular substitution system improve balance in patients with unilateral vestibular loss under altered somatosensory conditions from the foot and ankle? Conf Proc IEEE Eng Med Biol Soc. 2011;2011:1323-6.
81. Chen EW, Fu AS, Chan KM et al. The effects of tai chi on the balance control of elderly persons with visual impairment: a randomized clinical trial. Age Ageing. 2012;41(2):254-9.
82. Gabilan YP, Perracini MR, Munhoz MS et al. Aquatic physiotherapy for vestibular rehabilitation in patients with unilateral vestibular hypofunction: exploratory prospective study. J Vestib Res. 2008;18(2-3):139-46.
83. Hillier SL, McDonnell M. Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. Clin Otolaryngol. 2011;36(3):248-9.
84. Blatt PJ, Georgakakis GA, Herdman SJ et al. The effect of the canalith repositioning maneuver on resolving postural instability in patients with benign paroxysmal positional vertigo. Am J Otol. 2000;21(3):356-63.
85. Odman M, Maire R. Chronic subjective dizziness. Acta Otolaryngol. 2008;128(10):1085-8.
86. Staab JP, Ruckenstein MJ, Solomon D et al. Serotonin reuptake inhibitors for dizziness with psychiatric symptoms. Arch Otolaryngol Head Neck Surg. 2002;128(5):554-60.
87. Karlberg M, Magnusson M, Malmstrom EM et al. Postural and symptomatic improvement after physiotherapy in patients with dizziness of suspected cervical origin. Arch Phys Med Rehabil. 1996;77(9):874-82.
88. Lacour M, Bernard-Demanze L. Interaction between vestibular compensation mechanisms and vestibular rehabilitation therapy: 10 recommendations for optimal functional recovery. Front Neurol. 2014;5:285.
89. Whitney SL, Alghadir AH, Anwer S. Recent evidence about the effectiveness of vestibular rehabilitation. Curr Treat Options Neurol. 2016;18(3):13.
90. Krpic A, Savanovic A, Cikajlo I. Telerehabilitation: remote multimedia-supported assistance and mobile monitoring of balance training outcomes can facilitate the clinical staff's effort. Int J Rehabil Res. 2013;36(2):162-71.
91. Meldrum D, Herdman S, Vance R et al. Effectiveness of conventional versus virtual reality-based balance exercises in vestibular rehabilitation for unilateral peripheral vestibular loss: results of a randomized controlled trial. Arch Phys Med Rehabil. 2015;96(7):1319-28 e1.
92. Hesse S, Schmidt H, Werner C et al. Upper and lower extremity robotic devices for rehabilitation and for studying motor control. Curr Opin Neurol. 2003;16(6):705-10.
93. Guinand N, van de Berg R, Cavuscens S et al. Vestibular implants: 8 years of experience with electrical stimulation of the vestibular nerve in 11 patients with bilateral vestibular loss. ORL J Otorhinolaryngol Relat Spec. 2015;77(4):227-40.