NeuroRehabilitation xx (20xx) x–xx
DOI:10.3233/NRE-182524
IOS Press

Effect of vestibular rehabilitation on recovery rate and functioning improvement in patients with chronic unilateral vestibular hypofunction and bilateral vestibular hypofunction

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Abstract.
BACKGROUND: The minimal number of studies have documented the impact of Vestibular rehabilitation (VR) on the recovery rate of patients with Chronic Unilateral Vestibular Hypofunction (CUVH) and Bilateral Vestibular Hypofunction (BVH).
OBJECTIVES: The goal of the study was to show and compare the impact of vestibular rehabilitation (VR) in patients with CUVH and BVH.
METHODS: We analysed the data of 30 patients with CUVH and 20 with BVH treated with VR. The patients with CUVH during their eight-week treatment were controlled every two weeks, while the patients with BVH were controlled every three months during their one-year treatment; they filled in the DHI and ABC questionnaires every time.
RESULTS: In both groups of patients, there was significantly less disablement between the initial and final DHI scores (from 59-20 in CUVH and 74-41 in BVH group). There was a significant increase in the balance confidence between the initial and final ABC Scale in both groups of patients (from 49.5-90% in CUVH and 42-73% in BVH group).
CONCLUSIONS: Well-planned and individually adjusted system of vestibular exercises leads to a significant decrease in clinical symptoms and improvement of functioning and confidence in activities in both the CUVH and the BVH patients.

Keywords: Vestibular rehabilitation therapy, chronic unilateral vestibular hypofunction, bilateral vestibular hypofunction, outcome

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1. Introduction

Chronic Unilateral Vestibular Hypofunction-CUVH and Bilateral Vestibular Hypofunction-BVH are common diagnoses encountered by physicians. Common causes of CUVH are vestibular neuronitis or labyrinthitis, Ramsay Hunt syndrome, Ménière disease, trauma or head injuries, perilymphatic fistula, etc. The cause of BVH mostly remains unknown (Zingler, Weintz, Jahn, Huppert, Cnyrim, Brandt, & Strupp, 2009; Herdman, & Clendaniel, 2003). When it is known, it is mainly caused by different vestibulotoxic drugs, primarily macrolide antibiotics or secondly by bilateral Ménière disease (Bayat, & Saki, 2017; McDonnell, & Hillier, 2015; Brodovsky, & Vnenchak, 2013). The symptoms typical of peripheral vestibular lesions dominate in the clinical picture of acute unilateral vestibular hypofunction, such as rotational vertigo, followed by vegetative symptoms and peripheral nystagmus. In CUVH, persisting more than three months, the symptoms can vary from intense to slight or nonexistent depending on the size of the lesion and time course. In BVH, the loss of function of both labyrinths is observed as a chronic loss of postural control and insecurity while walking, which worsens in the dark or on an uneven surface. Sight dysfunction, such as vertical oscillopsia and blurring of vision is the most significant issue (25-50% of the affected) since it occurs during rapid head movement (Kim, Oh, Koo, & Kim, 2011; McGath, Barber, & Stoyanoff, 1989; Straube, Bronstein, & Straumann, 2012). While lying in bed, the patients with BVH do not perceive any distractions, and they usually associate the symptoms (often occurring after getting out of bed) to the tiredness caused by the illness (Strupp, Dietrich, & Brandt, 2013).

The diagnosis of CUVH is established by a typical clinical picture, and Fitzgerald-Hallpike bi-caloric test (the threshold value of unilateral weakness (UW) is set to $\geq$25%). The results are usually backed up by the results of vestibulo-ocular reflexes (VOR) collected in video Head Impulse Test (HIT) with the threshold set to $\leq$0.7. For a diagnosis of BVH, a significant bilateral deficit or loss of function of VOR should be confirmed by a clinical HIT for a high-frequency area, or, if inconclusive, by video HIT. In that case, the threshold of angular VOR is set up to $\leq$0,6 (during the angular speed of 150-300/s) (Strupp, 2016). For the low-frequency area, “a sum of both responses per ear <6°/sec can, therefore, be considered a safe criterion to point to BVP” (Strupp, Kim, Murofushi, Straumann, Jen, Rosengren, Della Santina, & Kingma, 2017) in Fitzgerald-Hallpike’s caloric test. If possible, the results of the Fitzgerald-Hallpike test are additionally supported by rotational testing, with the VOR threshold $\leq$0,1 (Kim, Oh, Koo, & Kim, 2011; Hain, Cherchi, & Yacovino, 2013; Agraval, Davalos-Bichara, Zuniga, & Carey, 2013).

The choice therapy for both groups of patients is the vestibular rehabilitation method, initiated on the medicinal practice of Cawthorne and Cooksey from the middle of the last century (Cooksy, 1946; Cowthorne, 1994). Vestibular rehabilitation gained greater popularity in the last few decades following numerous randomised clinical studies showing positive effects on the speed and the degree of patients’ recovery (Konrad, Tomlinson, Stockwell, Norré, Horak, Shepard, & Herdman, 1992; Horak, Jones-Rycewicz, Black, & Shumway-Cook, 1992; Herdman & Clendaniel, 2003; Topuz, Topuz, Ardiç, Sarhus, Ogmen, & Ardiç, 2004). The exercises are planned, individually assessed, and directed to solving the specific functional illnesses (Pavlou, Kanegaonkar, Swapp, Bamiou, Slater, & Luxon, 2012; McGibbon, Krebs, Wolf, Wayne, Scarborough, & Parker, 2004). They were found to accelerate the natural process of central vestibular compensation, lead to the elimination of symptoms and earlier return to the usual lifestyle activities. They also decrease the risk of falls, which can have difficult or sometimes fatal results in people of older age. (Szturm, Ireland, & Lessing-Turner, 1994; Herdman, Hall, Schubert, Das, & Tusa, 2007; Whitney, Alghadir, & Anwer, 2016; Hillier, & McDonnell, 2016). A natural course of these two vestibular entities is such that over time the patients with CUVH recuperate well symptomatically and functionally due to vestibular rehabilitation while the patients with BVH recover more slowly, without the recuperation of the affected labyrinth, but with the better balance due to vestibular exercises performed by alternative strategies over a prolonged period (up to two years) (Gillespie, & Minor, 1999; Zingler, Weintz, Jahn, Mike, Huppert, Rettinger, Brandt, & Strupp, 2008). None of the described published studies investigated exclusively and simultaneously VR impact on chronic unilateral and bilateral vestibular lesions, and there is a lack of specific knowledge on this subject. VR guidelines for peripheral vestibular disorders provide strategies for both unilateral and bilateral vestibular lesions, chronic but also acute (Hall, Herdman, Whitney, Cass, Clendaniel, Fife, Furman, Getchius, Goebel, Shepard, & Woodhouse, 2016). The study conducted by Zanardini et al. included only older patients and treated them just with Cawthorne-Cooksey exercises (Zanardini, Zeigelboim, Jurkiewicz, Marques, & Martins-Bassetto, 2007). The other approach included UVH and BVH, but VR was limited to the application of specific and innovative Wiimotion method (Chen, Hsieh, Wei, & Kao, 2012). There are very few reports that describe VR influence on BVH. Among them, Gilespie and Minor justified their poor results of VR in BVH by significant central comorbidity in the included cohort (Gillespie, & Minor, 1999). Herdman SJ et al. focused primarily on finding the factors that could be VR predictor of success (Herdman, Hall, Maloney, Knight, Ebert, & Lowe, 2015). The goal of this study was to investigate the influence of VR in patients with CUVH and BVH during eight-week and one-year follow-up. The effect of VR concerning the symptoms of the disease, the level of impairment, general physical status as well as regular social activities and balance confidence were analysed.

2. Patients and methods

2.1. Patients

We initially included 57 patients in the study, 32 with CUVH and 25 with BVH, arrived for the first time in the ENT Department from January 2016 to April 2017. The average time elapsed since the onset of the disease until the arrival to us was 4.95 for the CUVH and 8.9 months for the BVH group. The criteria for the involvement were as follows: the presence of symptoms longer than three months after start of the illness, the result of bedside and bicaloric tests, showing the uncompensated weakness of one (Directional Preponderance (DP) ≥35% and Unilateral Weaknes (UW) ≥25%) or both labyrinths (a sum of four irrigation ≤20°/sec) with Dizziness Handicap Inventory (DHI) score ≥40 (Jacobson, & Newman, 1990) and the Activities-specific Balance Confidence Scale (ABC) ≤66% (Myers, Powell, Maki, Holliday, Brawley, & Sherk, 1996). The exclusion criteria were as follows: an already obtained level of central vestibular compensation, the nonexistence of any symptoms, comorbidities of Ménière disease, vestibular migraine, and other fluctuating vestibular impairments. We also excluded patients with cognitive, visual, neurological or general motor impairment, as well as those who had any form of vestibular rehabilitation before coming to our department. By the end of the study, two patients from CUVH and five patients from BVH group were excepted from the study, due to their disrespect of treatment protocol, so the final number of examinees was 50 (30 patients in CUVH and 20 of them in BVH group).

2.2. Methods

During the initial visit, the patients undertook a Fitzgerald-Hallpike bi-caloric test, the part of videronystagmography (VNG) test battery (VNG system VN415/VO425, Interacoustics, Danmark). They completed DHI and ABC questionnaires for the first time. From the information obtained through the diagnostic process, physiotherapists' evaluation of disability and general physical condition individually tailored vestibular exercises for each patient, with a particular emphasis on home exercising prescribed, taking into account the fact that minimal interventions are usually the most effective. Gaze stability, substitution, and habituation exercises were individually adjusted to each patient in the CUVH group, with an emphasis on home exercise and gradual increase of exercise complexity, depending on the patient's condition. By relying mainly on degree and symmetry of labyrinth damage, BVH patients were subjected to substitution and adaptation exercises, also individually adjusted. We avoided ocular-motor (voluntary saccades and smooth-pursuit eye movements without head movement) exercises in both groups, which did not prove to contribute to the recovery of peripheral vestibular hypofunction (Herdman, Clendaniel, Mattox, Holliday, & Niparko, 1995; Herdman, Schubert, Das, & Tusa 2003; Herdman, Hall, Schubert, Das, &Tusa, 2007). The patients with CUVH during their eight-week treatment were invited every two weeks for checkups, while the patients with BVH were coming to checkups every three months during their one-year treatment; they filled in the DHI and ABC questionnaires every time.

2.3. Ethics

This study was approved by the Ethics Committee of the respective institution under an approval protocol number EP-215-08/17-10-4 according to the ethical standards of the institutional and national research committees, 1964 Helsinki Declaration and its later amendments. All the patients involved were adequately informed about the methods and objectives of this study. They have voluntarily accepted to participate in the survey, and informed consent was obtained from all participants involved in the study.

2.4. Statistics

Data were described using descriptive statistical methods. Differences in categorical variables were tested with Fisher's exact test. The normality of the distribution of numerical variables was tested by Shapiro-Wilk's test. The Friedman's test was used to detect the differences between dependent samples, and Mann Whitney U test for independent samples. The Cohen's d was used to detect effect size (Ivanković, Božiković, Kern, Suntešić, Kopjar, Tišljar, Luković, Car, & Vuletić, 1988; Marušić, 2013). All P values were two-sided. The level of significance was set at P of 0.05. The statistical analysis was performed using MedCalc Statistical Software version 18 (MedCalc Software bvba, Ostend, Belgium; http://www.medcalc.org; 2018).

3. Results

The research was conducted on 50 patients, among which 30 had unilateral and 20 bilateral vestibular hypofunction. The women were more common than men (35 vs 15). The age median amends to 64 years (interquartile range – IQR 54 to 69 years) without a significant difference in groups (Table 1). In the group of patients with CUVH, there was a significant decrease in symptoms of the disease from the first to the fourth measurement (Friedman test, P = 0,001). In the group with BVH, the symptoms have also decreased significantly between the first and the fourth measurements (Friedman test, P = 0,002) but not as much as in the CUVH group. There is no statistically significant difference in symptoms during the initial and final measurements related to the chronic unilateral or bilateral vestibular hypofunction (Table 2). Unilateral weakness in patients with CUVH was 41,5% (IQR 32% to 57,3%) while DP was 38,5% (IQR 35,2% to 42,8%). At those with BVH, vestibular sensitivity right (VSR) was 7,1°/s (IQR 3,9°/s to 9,9°/s), while on the left it was (VSL) 8,1°/s (IQR 3,8°/s to 10,5°/s). In the group of patients with CUVH, there was a significant increase safety of balance from the first (median 49.5, with 95% CI 24 to 73), to the fourth (median 90, with 95% CI 68 to 94) measurements (Friedman test, P < 0,001). In the group with BVH, there was a great increase in the safety of balance between the first (median 42, with 95% CI 29 to 63) and the fourth (median 73, with 95% CI 62 to 83) measurements (Friedman's test, P = 0,002). There was no significant difference in the safety of balance between the groups in the first measurement. In the final measurement, there was a significantly higher safety of balance in CUVH, the median of 90 (IQR 72 – 93) as opposed to 73 (IQR 65 – 80) in BVH group (Mann Whitney U test, P = *0*,04) (Table 3). The effect size for DHI questionnaire is good and almost equal between the groups at initial and final measurement, while for the ABC, the effect size between the groups at final measurement is good (0.457) (Tables 2 and 3).

4. Discussion

The average age of patients in this study revealed that the vestibular rehabilitation was prescribed mostly to people of older age (Table 1). The patients with CUVH were somewhat older (median 64) compared to patients with BVH (median 59) with the average of both groups (median 63). Besides the previously mentioned underlying causes of vestibular hypofunction, the process of ageing and correlated degenerative changes could also affect the balance. In older people, the vestibulo-ocular reflex is affected and this is related to the disintegration of the sensory cells. It is usually confirmed by rotational tests, but VEMP can serve as evidence of otolithic function worsening (lowering of the amplitude due to the disintegration of the macular sensory cells and the elongation of latency due to an aggravated processing in the brain core) (Rosenhall, 1973; Rauch, Velazquez – Villasenor, Dimitri, & Merchant, 2001; Iwasaki, & Yamasoba, 2015; Brantberg, Granath, & Schart, 2007; Su, Huang, Young, & Cheng, 2004). The study of an American National Health and Nutrition Examination Survey (NHANES, 2001-2004) showed that the vestibular dysfunction escalated over time, so almost 85% of people aged 80 or more have vestibular dysfunction. Besides, the people with vestibular impairments have eight times higher a risk of falling, which is worrying due to the increased morbidity and mortality associated with falls (Agrawal, Carey, Della Santina, Schubert, & Minor, 2009; Quitschal, Fukunaga, Ganança, & Caovilla, 2014), as well as the enormous expenses of the related healthcare (Stevens, Corso, Finkelstein, & Miller, 2006; Dellinger, & Stevens 2006). The division of patients according to gender (Table 1) shows that there was a greater ratio of women in both groups, in the ratio of even above 2:1. This correlated with the literature data reporting the ratio of women: men at 2,7:1 (Neuhauser, 2016; Lempert, & Neuhauser, 2009). During the first checkup, the caloric test measured the average values of UW for patients with CUVH at the level of 44,1 ± 14,3%. For patients with bilateral vestibulopathy, the vestibular sensitiv-

Table 1
Gender and age by groups

	Chronic unilateral vestibular hypofunction	Bilateral vestibular hypofunction	Total	P
Gender				
Men	9/30	6/20	15/50	>0.99*
Women	21/30	14/20	35/50	
Median age [Median (IQR)]	64 (54–69)	59 (54–66)	63 (54–66)	0.54†

*Fisher's exact test; †Mann Whitney U test.

Table 2
Values of DHI classification by measurements and types of vestibular hypofunction

	Chronic unilateral vestibular hypofunction (n=30)			Bilateral vestibular hypofunction (n=20)			P†	Effect size (r)‡
	Median (25%-75%)	95% CI	P*	Median (25%-75%)	95% CI	P*		
DHI1	59 (50–76)	4.7–84.4		74 (60–84)	58–88		0.17	0.306
DHI2	47 (26–54)	26–62.4	**0.001**	64 (55–68)	52.5–71	**0.002**	0.08	0.292
DHI3	30 (22–62)	21–70		56 (30–61)	40–62.4		0,21	0.321
DHI4	20 (2–48)	2–53.3		41 (34–46)	29–48		0.11	0.355

*Friedman's test; †Mann Whitney U test; ‡between unilateral and bilateral hypofunction.

Table 3
ABC scale values by measurement and type of vestibular impairment

	Chronic unilateral vestibular hypofunction (n=30)			Bilateral vestibular hypofunction (n=20)			P†	Effect size (r)‡
	Median (25%-75%)	95% CI	P*	Median (25%-75%)	95% CI	P*		
ABC1	49.5 (25–70)	24–73		42 (30–60)	29–63		0.60	0.119
ABC2	73 (51–80)	48–82	**<0.001**	48 (43–55)	40–58	**0.002**	0.34	0.213
ABC3	75.5 (57–81)	46–85		65 (60–68)	57–75		0.09	0.324
ABC4	90 (72–93)	68–94		73 (65–80)	62–83		**0.04**	0.457

*Friedman's test; †Mann Whitney U test; ‡between unilateral and bilateral hypofunction; ABC1, 2, 3, 4 - first, second, third and fourth measurement.

ity was 7.4 ± 3.4°/s and 7.4 ± 3.7°/s on the right and left ear, respectively. The literature reports the vestibular sensitivity physiologically between 20°/s and 100°/s, while on the other hand, the values under 20°/s are a sign of a decreased vestibular sensitivity, and the UW $\geq$20% is taken as a significant disproportion in the labyrinth response. The advantages of early vestibular rehabilitation application for the patients is that it leads to a better balance during walking, even during the initial phase of the disease, thus decreasing the probability of falls and the patients' subjective symptoms. (Enticott, O'leary, & Briggs, 2005; Arnold, Stewart, Moor, Karl, & Reneker, 2017). During the planning of vestibular rehabilitation for patients with chronic peripheral vestibular impairments, it was essential to determine the nature of the patient's functional problems. For personal difficulties and limited daily activities, we used standardised DHI and ABC questionnaires. They also assist in the follow-up and evaluation of the results from patients with CUVH and BVH. By using the results of 4 repeated DHI and ABC tests (Tables 2 and 3), we showed that in patients with CUVH there was a statistically significant decrease in symptoms of illness and improvement of functioning and security in activities from the initial low to a high level after VR. The analyses of both questionnaires showed a statistically significant difference between all tests except the second and third test revealing a constant improvement during vestibular rehabilitation, and indicated that there was a significant recovery at the final stages of treatment compared to the initial condition. In patients with BVH, there was also a statistically significant decrease in symptoms of illness and improvement of balance confidence (Tables 2 and 3). It was observed that the patients with BVH recuperate with different dynamics and that the patients should be additionally motivated to regularly come for checkups thus enabling more precise data to be collected. In some earlier studies, similar results were obtained showing an almost equal recovery in both groups of patients (Karapolat, Celebisoy, Kirazli, Ozgen, Gode, Gokcay, Bilgen, & Kirazli, 2014; Brown, Whitney, Wrisley, & Furman, 2001; Jeong, Jung, Lee, Suh, Kwak, & Kim, 2017). Herdman SJ has confirmed this in one of their more recent studies where it was claimed that the vestibular rehabilitation was useful for a majority of BVH patients but not for all. The older patients recovered more difficulty than the younger ones, and those with poorer initial results showed a more modest recovery (Herdman, Hall, Maloney, Knight, Ebert, & Lowe, 2015). The comparison of results in the final DHI test was surprising, since those with CUVH showed the better final result, even though not statistically significant, compared to those with BVH. The reason for this could be the greater dispersion of data in the group of patients with CUVH (Table 2). The comparison of the final ABC test after VR (Table 3) revealed a statistically significant improvement of security in activities in patients with CUVH compared to those with BVH. However, in both groups, there was an increase to a high level of functioning and confidence, especially in patients with CUVH. The obtained results are expected because the patients with BVH mostly show up for VR much later having more significant impairment of the vestibular apparatus. When considering the expected length of VR treatment, eight weeks for CUVH and one-year for BVH was set up based on our experience but also taking into account previous recommendations (Hall, Herdman, Whitney, Cass, Clendaniel, Fife, Furman, Getchius, Goebel, Shepard, & Woodhouse, 2016). No study specifically examines the decision of ending the vestibular physiotherapy in patients with CUVH and BVH (Herdman, & Clendaniel, 2014). Implicit reasons for the cessation of the therapy are the disappearance of symptoms, achievement of the therapeutic goals, or reaching progression plateau (Hederman, Hall, & Delaune, 2012; Herdman, 2013). Therefore, the patients with BVH should be additionally motivated and encouraged by their physicians to commit to long-term exercising. They need to be aware that the process of recovery often takes a lot of time and hard work and that their postural control will never be the same as before, but exercises can significantly improve it. The results obtained in this study are improved over the current literature quotations, potentially due to several reasons. One of them is a sample of patients with chronic peripheral lesions of the labyrinth were not too much affected by labyrinthine lesions. Patients with CUVH had a significant but not excessive degree of labyrinth damage (UW was 41.5% with IQR 32% to 57.3%). In patients with BVH, a significant bilateral labyrinth lesions were observed, without relevant asymmetry, far below the established criteria for the entrance into the study, but far above the recent guidelines for bilateral vestibulopathy (Strupp, Kim, Murofushi, Straumann, Jen, Rosengren, Della, Santina, & Kingma, 2017) (vestibular sensitivity right (VSR) was 7.1°/s, while on the left it was (VSL) 8.1°/s). We also think that the exclusion of patients with any additional comorbidities from the study has also significantly contributed to the improved study outcomes. Although our sample is relatively small, it is sufficient for a statistical analysis, which shows high or at least good effect size and statistically significant p for both groups and both questionnaires. The important contribution to the improved recovery results of our patients with chronic peripheral vestibular hypofunction could also be attributed to the good cooperation of a well-organised team of experts consisting of otorhinolaryngologist, neurologist, physiotherapy specialist, and well-educated and trained physiotherapists. According to the state of impairment, disability, and functional performance of every single patient, they performed very carefully selected and individually tailored exercises including timely and regularly conducted controls. Thus, ineffective ocular motor exercises were avoided in both groups of patients, while for the BVH group habituation exercises were not prescribed as they are not just inefficient but may also be counterproductive for these patients.

5. Conclusions

Our results show that a well-planned and individually adjusted system of vestibular exercises leads to a significant decrease in clinical symptoms and improvement to the high level of functioning and confidence in activities in both the CUVH and the BVH patients. The patients with CUVH experienced a better and faster recovery. They had significantly better results in functioning improvement compared to BVH patients. Given the minimal number of studies that have so far documented the impact of VR on the recovery rate of patients with chronic peripheral vestibular hypofunction, additional efforts should be made to find potential indicators that exert a positive or negative impact on the outcome of rehabilitation therapy.

Acknowledgements

All authors undertook conceptual thinking around the paper focus, interpretation of data, discussion formulation and the write-up. All authors revised and approved the final copy of the manuscript. We would like to thank Kristina Kralik, PhD, for statistical assistance, Tihomir Zivic, PhD, for English language assistance, and Olivera Cejic, graduated physiotherapist for the work with patients and data collection.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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