Auditory and Vestibular Research

The Effect of Whole Body Vibration and Galvanic Vestibular Stimulation Combined with Vestibular Rehabilitation on Balance in patients with Uncompensated Unilateral Vestibular Neuritis

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Highlights:
- Vestibular rehabilitation, vibration and galvanic stimulation improve balance in UVN
- Combined rehabilitation shows more improvement in posturography, vHIT and DHI in UVN

Abstract
Background and aim: Previous studies have demonstrated that uncompensated Unilateral Vestibular Neuritis (UVN) is a most prevalent cause of dizziness. Despite the many advantages, use of Conventional Vestibular Rehabilitation (CVR) in UVN patients have limitations. The use of tool-based rehabilitation methods can be more pleasant to patients and encourage them to complete the rehabilitation course. This study aimed to compare the effects of combined Whole Body Vibration (WBV), Galvanic Vestibular Stimulation (GVS) and CVR in patients with UVN.
Methods: UVN patients in the age range of 30 to 50 years were randomly divided into three groups with 17 participants each. first group received of CVR, the second group received CVR+WBV, and the third group received CVR+WBV+GVS, which included four weeks of CVR, twenty 5-minute sessions of WBV and eight 20-minute sessions of GVS. Outcome measurements were postural control parameters, Vestibulo-Ocular Reflex (VOR) gain asymmetry, joint position sense error (JPSE) and Dizziness Handicap Inventory (DHI) scores that were assessed at baseline and after four weeks.
Results: There was a significant improvement in all measured variables after the CVR, CVR+WBV and CRV+WBV+GVS treatments. Moreover, the CVR+WBV and CRV+WBV+GVS groups showed significantly greater improvement than the CVR group in posturography results, JPSE and DHI score ($p < 0.05$) except VOR gain asymmetry ($p > 0.05$).
Conclusion: CVR, CVR+WBV and CRV+WBV+GVS treatments effectively improve balance function. CVR+WBV and CRV+WBV+GVS training shows additional therapeutic effects in UVN patients. When CVR combined with WBV and GVS, shows additional therapeutic effects in UVN patients.
Keywords: Vestibular neuritis, vestibular rehabilitation, whole body vibration, galvanic vestibular stimulation

Introduction

Uncompensated unilateral vestibular neuritis (UVN) leads to complex symptoms and disorders in both static and dynamic states, typically affecting eye movement and postural control [1-4]. UVN is the third most common cause of vertigo after Benign Paroxysmal Positional Vertigo (BPPV) and Ménière's disease. Patients with uncompensated UVN often experience imbalance, ataxia (especially in low-visibility conditions or on uneven surfaces), and oscillopsia during movement [5-7].

Currently, the most common treatment and rehabilitation approach for unilateral vestibular disorders involves structured physical exercises and movements in the form of conventional vestibular rehabilitation (CVR) [3, 8, 9] . Although CVR offers many advantages, it also presents limitations. CVR requires patients to have an adequate physical condition, actively participate in the exercises, and provide appropriate feedback. In today's society, due to increasingly sedentary lifestyles, many patients find it difficult to participate in CVR. Additionally, CVR places less emphasis on proprioception, which is crucial for calibrating vestibular inputs at the perceptual level because it is the only signal that consistently provides reliable information about changes in head position relative to the trunk [3]. The base of vestibular rehabilitation is to improve and accelerate the recovery process in the vestibular system. In this approach, using the mechanism of central plasticity (adaptation, habituation, and substitution), static and dynamic postural stability is increased and vestibular-ocular interactions are improved in situations with conflicting sensory information [10]. Research has demonstrated that complete recovery is often not achieved through central compensation exercises alone. Alternative methods like proprioceptive training can yield more effective and efficient results. Relying on a single rehabilitation method may not achieve all rehabilitation goals; however, integrating proprioceptive and vestibular inputs into a program can enhance rehabilitation outcomes [11].

In recent years, technological advancements have introduced additional methods: Whole body vibration (WBV) and galvanic vestibular stimulation (GVS). WBV, a mechanical vertical stimulation technique that delivers vibrations to proprioceptors. WBV has demonstrated potential effects on sensorimotor performance in various populations, including the athletes [12], elderly, healthy adults, and children with cerebral palsy (CP) [13]. So far, no study has used WBV stimulation in the rehabilitation of patients with vestibular deficit. WBV is a safe, easy-to-use clinical intervention, particularly for individuals who cannot actively participate in traditional exercises. It is hypothesized that vibration provides proprioceptive input to the central nervous system, which subsequently adjusts the weight of proprioceptive signals in the vestibular system, ultimately improving balance performance. In WBV, vibration is applied to the body through a plate. The human body acts like a spring and stores mechanical energy. When the body moves upward under stimulation, energy is stored and when it falls downward under the influence of gravity, energy is released. During these movements, muscles, tendons, and joints work together to manage the flow of energy through the body [14]. Studies have shown that vibratory sensory stimuli are transmitted to muscle spindle fibers and Golgi tendon organs, activating alpha motor neurons [15].

Recently, GVS has been introduced as an another stimulus that can affect the vestibular system. In study by Sung Nam et al. investigate the ameliorating effects of sinusoidal GVS on vestibular compensation by using a mouse model of unilateral labyrinthectomy (UL). This study show that GVS intervention significantly accelerated recovery of locomotion and improved VOR gain compared to the non-GVS groups. GVS is a noninvasive technique that activates various parts of the peripheral vestibular system and vestibular nuclei through electrodes placed on the mastoid. In normal individuals, GVS improves dynamic gait, postural and motor stability [16,17].

Considering that previous studies had mainly proven the effect of nGVS in improving the balance function of patients with vestibular deficit. Direct circuit galvanic vestibular stimulation (dcGVS) had been used less frequently, so in this study, we used dcGVS in the third group. Combining physical exercises with proprioceptive vibration stimulation and GVS may result in simultaneous enhanced effects. Therefore, this study aimed to investigate using WBV and GVS as a complementary rehabilitation approach alongside CVR in treating UVN.

Methods

The study was conducted as an interventional with the approval of the Ethics Committee of Shahid Beheshti University of Medical Sciences (Code: IR.SBMU.RETECH.REC.1403.034). All participants were informed about the study's aim and obtained written consent. The study population consisted of individuals aged 30 to 50, referred to the Tohid Balance Evaluation and Rehabilitation Clinic in Isfahan. An audiologist performed all assessments and interventions. Inclusion criteria required participants to have one or more subjective complaints for several days: disequilibrium, gait instability, vertigo/dizziness, oscillopsia, or spontaneous nystagmus.

Additionally, participants needed a clinical diagnosis of uncompensated, non-progressive UVN confirmed by thermal caloric irrigation, with a canal paresis of more than 25%, and a normal oculomotor VNG test. Exclusion criteria included the presence of a disability, nausea, or vomiting during the tests or rehabilitation sessions, prior vestibular rehabilitation, or any acute medical conditions that could limit assessments or treatment options [18].

A total of 51 participants met the inclusion criteria, and six patients were excluded from the study. Finally, 45 participants (23 males and 22 females, mean age 39.90±7.02) completed the trial. The patients were randomly allocated into three intervention groups: 1) the CVR group, which received four weeks of vestibular rehabilitation, 2) the CVR+WBV group, which received four weeks of vestibular rehabilitation plus twenty 5-minute sessions of WBV stimulation and 3) the CVR+WBV+GVS, which received four weeks of vestibular rehabilitation plus twenty 5-minute sessions of WBV stimulation and eight 20-minute sessions of GVS. A simple random sampling method was used to assign the three treatment groups. A 1:1 allocation ratio was applied using a randomization sequence generated by the Random Allocation Software.

Outcome Measures

Video head impulse test

We used small, lightweight glasses manufactured by Otometrics with 250 frames per second resolution. The subject focused on a point in dim light located 91 cm away on the wall. The experimenter stood behind the patient's head and delivered ten impulses at a speed of 150–200°/s at unpredictable times and directions, aligned with each pair of semicircular canals. to measure VOR in every semicircular canal direction, Head impulses were given in the yaw axis to test the left and right horizontal canals. The patient's head was turned approximately 35 to 45 degrees to the right to examine the right posterior and left anterior canals. The head was turned 35 to 45 degrees to the left to assess the left posterior and right anterior canals, and the test was performed. Quantitative values were obtained by calculating the gain of eye movement relative to head movement. If present, covert and overt compensatory saccades were recorded during and after the head impulse, respectively [19].

Cervical joint position sense error test

This test involved a laser pointer attached to a headband worn by the patient. The patient sat on a chair 90 cm away from the wall and focused the laser light on a predetermined point. To prevent any trunk movement, the patient's torso was secured to the back of the chair with a strap. The patient was instructed to close their eyes, rotate their head to the extreme right or left (as far as possible without causing severe pain), and then return to the initial point. In order to avoid fatigue and increase the accuracy of the test, movements were performed at 15-second intervals. The average deviation from the midpoint after right and left rotations was measured in millimeters, and the Joint Position Sense (JPS) error was calculated in degrees. The test was repeated six times for each side to ensure accuracy, and the average error was obtained from these six repetitions.

Dizziness handicap inventory

The Persian version of this questionnaire was developed and validated to assess the degree of disability caused by dizziness. The questionnaire consists of 25 questions, each with three response options: *yes* (4 points), *sometimes* (2 points), and *no* (0 points). The patient completed the questionnaire with assistance from the examiner if needed. Depending on the patient's ability, it took between 10 and 15 minutes to complete. Improvement in the questionnaire scores indicates a reduction in disability, while a lack of change suggests no progress in response to the intervention.

Posturography test

The posturography test was conducted using a device manufactured by Synapsys. Before the test, the procedure was explained to the participant. The subject stood barefoot on a designated spot on the device's platform. The size of the subject's foot was measured to ensure proper placement on the platform. The participant then stood upright without leaning or using any support. Initially, the pressure distribution across the sole was measured. Following this, the range of stability for forward, backward, and lateral movements was assessed and limits of stability (LOS) and total score (CS) of the Sensory Organization Test (SOT) in both the anteroposterior (AP) and mediolateral (ML) directions were obtained. The sensors embedded in the platform recorded and calculated the extent of movement fluctuations in various directions [20].

Rehabilitation Methods

Conventional vestibular rehabilitation exercises

CVR was performed based on previous studies over four weeks, with three sessions per week, each lasting one hour. The sessions took place in the clinic under the supervision of an operator. In the conventional vestibular rehabilitation method, physical exercises were used for rehabilitation. These exercises included Vestibulo-Ocular Reflex (VOR) exercises, saccadic eye movement exercises, and Cawthorne-Cooksey exercises [21,22]. To do VOR exercises the patient has to sit facing a sticker on a wall 3 feet away and keeps his/her eyes on the wall at all times during exercise and turn rhythmically his/her head a little to the right and then to the left for at least 1 minute. During saccadic eye movement exercises, the patient has to keep his/her head still and moves only the gaze quickly from the right to the left target, then back from the left to the right target. She/he has to repeats the back-and-forth eye motion for 1 minute. Cawthorne-Cooksey exercises are a set of head, eye, and body movements in prone, sitting, standing, and walking positions that can improve imbalances through different compensatory mechanisms.

Whole body vibration method
WBV is a vertical mechanical stimulation method that provides mechanical vibration to proprioceptive receptors. Commercial WBV usually provides a frequency below 50 Hz and is safe [23]. For the WBV intervention, we used a commercial-grade machine (LV-1000, X-trend, Taiwan) with a presentation frequency of 20 Hz and constant sine wave vibrations (range: 0–4 mm). Participants underwent WBV for five minutes in each session while standing normally. The exercises were performed five times weekly for four consecutive weeks [24].

Galvanic vestibular stimulation
In the galvanic vestibular stimulation method, electrical stimulation was performed bilateral bipolar by using a direct current stimulator (Tanin Pardaz Pasargad Co, Iran). First, the electrode placement sites on the mastoid bones behind each ear were cleaned using a cleaning gel. Electrocardiography electrodes were attached to the skin and the impedance should be below 5 kΩ. Cathodically stimulating, by placing the cathode electrode on the mastoid of the lesion side and the anode electrode on the opposite mastoid, at an intensity level of 100 microamperes above the skin threshold. while the subject was sitting with closed eyes for eight sessions (two sessions per week for four weeks) and 20 minutes per session. It should be noted that the skin threshold is achieved in 50 microampere steps, starting from an intensity level of 200 microamperes.

Statistical Analysis
Descriptive statistics were reported as mean and standard deviation. The Kolmogorov-Smirnov test was used to assess the normality of the data. An one-way ANOVA was applied to compare the baseline characteristics of normally distributed data, while the Chi-Square test was used to compare the sex distribution between the three groups. For within-group comparisons, a paired t-test was employed for normally distributed data, and Cohen's d (d) was used to measure the effect size, with values categorized as small (0.2), medium (0.5), and large (0.8). An one-way ANOVA test was also used to compare variables between the three groups. For pairwise comparisons, Bonferroni-corrected multiple comparisons between the three treatment groups was used

Results
Demographic characteristics of the participants presents in table 1. As shown, there was no significant difference in age, gender, or unilateral weakness between the three rehabilitation groups (Table 1).

Within-Group Comparisons of Outcome Measures
The results of within-group comparisons, as shown in Table 2, indicate that three rehabilitation groups demonstrated significant improvements in VOR gain, JPS error, posturography results, and dizziness handicap inventory (DHI) scores ($p < 0.05$).

Between-Group Comparisons of Outcome Measures
According to ANOVA test results, the difference between groups were statistically significant for JPS error, posturography results, and DHI questionnaire scores ($p < 0.05$) and the results of pairwise comparisons with Bonferroni-corrected multiple comparisons as shown in Table 3. However, the difference in VOR gain improvement between the three groups was not statistically significant ($p > 0.05$, Table 3).

Discussion

This study investigated the effects of combined vibration, galvanic and vestibular rehabilitation on balance in patients with uncompensated UVN. To our knowledge, the effect of WBV stimulation on improving outcomes for patients with uncompensated UVN has yet to be studied. The results demonstrated that all three rehabilitation methods significantly improved all measured outcomes, with the CVR+WBV and CVR+WBV+GVS groups showing greater improvements in all components except VOR gain asymmetry compared to the CVR group alone. Additionally, the effect sizes for all outcomes were larger in the CVR+WBV and CVR+WBV+GVS groups than in the CVR group.

The current study observed a significant decrease in VOR gain asymmetry, particularly in the horizontal canals, in three groups after rehabilitation. This finding suggests improved gait stability during head movement in patients with UVN. Notably, the increase in VOR gain for the horizontal semicircular canal on the affected side was more significant than for the vertical canals in three groups after rehabilitation. This was accompanied by a notable reduction in the VOR gain of the horizontal canal, compared to the other two canals, in the three groups. The foundation of conventional vestibular rehabilitation lies in accelerating the recovery of the vestibular system by leveraging the central neuroplasticity mechanisms of adaptation, habituation, and substitution. These processes induce active neural changes in the brainstem and cerebellum in response to sensory conflicts caused by vestibular pathways. Ultimately, this leads to improved static and dynamic postural stability and enhanced VOR gain and yaw stability during head movements [25].

Additionally, the results of this study did not show a significant difference in VOR gain asymmetry reduction between the three groups. however, the horizontal canal results are close to significant. These results are expected because in very few uncompensated UVN patients the posterior and anterior canals were involved. The improvement of the VOR gain following vestibular rehabilitation has been reported in several studies [26,27], but so far no study has been conducted on the improvement of VOR gain as a result of WBV. Although CVR exercises effectively improved VOR gain in CVR group, but WBV and GVS groups did not directly affect VOR outcomes.

In this study, the cervical JPS test was performed before and after rehabilitation. The significant reduction in cervical JPS error, observed on both sides, was more pronounced in the CVR+WBV and CVR+WBV+GVS groups than in the CVR. But no difference was observed between groups 2 and 3. This means that GVS has no effect on the JPS results. The use of GVS improves the processing of sensory information in the vestibular system. Vestibular signal detection thresholds are reduced, resulting in the processing of weak and subthreshold vestibular inputs, and ultimately, it improves information processing in the neurons of the central vestibular system and the formation of vestibular-spinal reflexes [28]. And vestibular information is not required to correctly detect head movements relative to the body, and cervical proprioceptive information is sufficient for this function. During vibration, the central nervous system receives proprioceptive input, which alters the weight of proprioceptive signals in the vestibular system, ultimately enhancing balance performance. Sensory substitution is an essential component in vestibular rehabilitation to maintain the postural control of uncompensated UVN patients. It relies on increasing residual inputs by manipulating visual and somatosensory cues. Sinusoidal vibration can stimulate proprioceptive receptors, such as muscle spindles and joint mechanoreceptors [29]. Since WBV improves muscle strength and balance, and muscle stiffness and joint stability can be modified through mechanoreceptor activity via gamma efferent stimulation, this type of vibration has the potential to train and alter proprioception throughout the body. The improvement in proprioceptive sensation likely occurs through type I afferent fibers and alpha motor neurons and an increase in the number of type II muscle-contributing fibers. It is well established that proprioceptive input from type I afferent fibers pathways is crucial in generating isometric contractions [30]. The increase in isometric strength following WBV is likely due to a positive proprioceptive feedback loop. Furthermore, the underlying mechanisms of WBV are not limited to muscle mechanics and proprioception but also involve hormonal and non-hormonal pathways. Changes in testosterone, growth hormone, growth factors, epinephrine, and norepinephrine levels have been observed following WBV [31].

The results of this study are consistent with the study by Khavarghazalani et al. which found that using GVS along with vestibular rehabilitation led to improvements in balance in UVN patients [32]. It seems that GVS mainly changes vestibular afferent fibers with irregular discharge that transmit phasic or high-frequency information. This is significantly important for the restoration of the dynamic balance function after UVN. Based on the results of past studies, the use of GVS modulates the activity of calcium and sodium dependent channels and the activity of N-Methyl-D-Aspartate (NMDA) receptors and creates a mechanism similar to Long-Term

Potentiation (LTP). It is possible that the simultaneous use of the two methods of interventions causes stimulation of more parts and has higher effects on the performance of balance function in UVN patients.

Therefore, incorporating WBV and GVS alongside vestibular rehabilitation can be a valid and effective strategy to enhance neural plasticity and alter proprioception. Changes in proprioceptive in patients with UVN may serve as a compensatory strategy for reduced vestibular function. Sensory substitution is a critical component of vestibular rehabilitation, helping to maintain postural control in patients with unilateral vestibular deficits during standing and walking. Conventional vestibular rehabilitation focuses on enhancing residual inputs by manipulating visual cues (e.g., eyes open, eyes closed, and optokinetic stimulation) and balance control (e.g., standing on a fixed surface, foam, or a moving surface), often combining both protocols [33].

In this study, a significant increase in the LOS in the postural test was observed in all groups after the rehabilitation, indicating improved patient stability. Based on the results of the DHI, the significant improvement in LOS after one month of rehabilitation suggests better patient performance in daily activities. As previously mentioned, postural control relies on sensory information transmitted from the visual, vestibular, and somatosensory systems. The body's sensory system provides information about the support surface and joint angles, the visual system offers environmental cues, and the vestibular system delivers data regarding the head's angular velocity, linear acceleration, and orientation concerning gravity [34]. One of the postural control strategies is the ankle strategy. When a person is on a firm, smooth surface, movements occur within the range of the ankle joint. In this position, the upper and lower body move together, causing the body to resemble an inverted pendulum in the sagittal plane, maintaining stability. Vestibular input is unnecessary to initiate or execute a normal ankle strategy and proprioceptive information alone is sufficient to control it. The difference in the LOS outcomes between the first group and the second group after the rehabilitation period is likely attributable to vibration-based stimulation in the second group's rehabilitation program.

In a study conducted by Tseng, WBV stimulation and heat therapy were used for individuals over 45 years of age who did not have a regular exercise regimen. WBV was administered for three consecutive months, with three sessions per week, each lasting 5 minutes, and heat therapy for 20 minutes at a temperature of 40°C. After the intervention, LOS and muscle strength were assessed using a posture machine, and flexibility was evaluated with the sit-and-reach test. A significant improvement in muscle flexibility was observed in both the WBV and WBV + HT groups, which is consistent with the findings of our study.

In our research, the CS of the SOT in both the AP and ML directions increased significantly after the rehabilitation in the three groups. This increase was more pronounced in the combined rehabilitation groups (CVR+WBV and CVR+WBV+GVS) than in the CVR-only group. In contrast to our findings, Eder et al. found that adding Galvanic Vestibular Stimulation to the vestibular rehabilitation program in patients with bilateral vestibular hypofunction (BVH) did not result in more effective outcomes compared to CVR alone in postural tests and questionnaires. This discrepancy may be attributed to differences in the type and duration of the CVR program, patient groups, evaluation methods, or the use of GVS at varying intensities. Therefore, incorporating WBV and vestibular rehabilitation can enhance balance by improving muscle strength and altering proprioception. The DHI scores significantly improved after the rehabilitation period in all groups. The DHI reflects the patient's self-perception of the severity of dizziness and the degree of instability caused by vestibular defects in daily life. A notable difference in the rate of improvement in DHI scores was observed between the three rehabilitation groups. Due to time constraints, we could not examine the long-term effects of WBV rehabilitation. We suggest an investigation of the long-term effects WBV in future studies.

Conclusion

Our study supports that combining CVR with GVS and WBV in patients with uncompensated UVN leads to more significant improvements than CVR alone. It highlights the enhanced effectiveness of using three rehabilitation methods together. Clinically, representing a new combined rehabilitation package for patients with uncompensated unilateral vestibular neuritis could speed up recovery.

Statements and Declarations

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Competing Interests: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was conducted with the approval of the Ethics Committee of Shahid Beheshti University of Medical Sciences (Code: IR.SBMU.RETECH.REC.1403.034).

Consent for publication: Consent for publication was obtained for every individual person's data included in the study.

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Table 1. Demographic characteristics of the participants

Characteristics	CVR(17)	CVR+WBV(17)	CVR+WBV+GVS (17)	P
Age	39.82 (7.44)	39.94(6.05)	40.24(5.31)	0.960*
Sex (male/female)	10/7	9/8	8/9	0.790**
Unilateral weakness (percent)	44.14(9.71)	45.47(12.85)	43.23 (9.40)	0.737*

CVR; conventional vestibular rehabilitation, WBV; whole body vibration, GVS; galvanic vestibular stimulation. * one-way ANOVA, ** Chi-Square

Table 2. Within-group comparisons of outcome measures

PARAMETER	GROUP	BEFORE INTERVENTION		AFTER INTERVENTION			
		mean	**SD**	**mean**	**SD**	p*	d/power
HORIZONTAL VOR ASYMMETRY	CVR	27.19	14.90	18.19	5.32	**<0.001**	1.56
	CVR+WBV	28.82	22.54	14.83	10.75	**<0.001**	1.35
	CVR+WBV+GVS	24.95	13.61	7.80	5.32	**<0.001**	1.81
ANTERIOR VOR ASYMMETRY	CVR	8.28	4.69	6.48	4.51	**0.001**	1.03
	CVR+WBV	9.25	5.41	7.36	3.57	0.06	0.52
	CVR+WBV+GVS	10.17	9.52	9.54	6.52	0.27	0.29
POSTERIOR VOR ASYMMETRY	CVR	10.48	10.61	8.27	8.71	**0.004**	0.88
	CVR+WBV	6.19	6.81	5.47	6.81	**0.05**	0.55
	CVR+WBV+GVS	8.26	5.54	8.10	5.39	0.96	0.01
JPS ERROR	CVR	3.58	0.74	2.89	0.58	**<0.001**	2.48
	CVR+WBV	3.67	0.55	2.18	0.32	**<0.001**	3.36
	CVR+WBV+GVS	3.57	0.31	1.97	0.10	**<0.001**	5.81
ML DISPLACEMENT	CVR	55.06	3.17	67.73	4.04	**<0.001**	12.58
	CVR+WBV	54.76	3.88	72.07	62.4	**<0.001**	16.30
	CVR+WBV+GVS	55.35	3.02	82.00	4.44	**<0.001**	15.58
AP DISPLACEMENT	CVR	47.71	2.59	56.60	3.31	**<0.001**	10.91
	CVR+WBV	47.76	2.99	62.07	5.14	**<0.001**	4.84
	CVR+WBV+GVS	47.35	2.12	67.60	3.48	**<0.001**	14.03
LOS	CVR	67.88	7.41	74.33	9.30	**<0.001**	2.27
	CVR+WBV	67.18	7.56	82.13	9.47	**<0.001**	6.79
	CVR+WBV+GVS	66.82	5.97	88.80	7.20	**<0.001**	9.35
DHI SCORE	CVR	43.53	14.65	34.00	13.93	**<0.001**	2.83
	CVR+WBV	43.54	15.93	23.20	12.55	**<0.001**	3.05
	CVR+WBV+GVS	42.00	15.41	13.33	6.44	**<0.001**	2.61

VOR; vestibulo-ocular gain, JPS; joint position sense, ML; mediolateral, AP: anterior-posterior, LOS; limit of stability, DHI; dizziness handicap inventory; CVR; conventional vestibular rehabilitation, WBV; whole body vibration, GVS; galvanic vestibular stimulation. Bold numbers: p<0.05, * paired t-test; d/Power; effect size with Cohen's d (small=0.2, medium=0.5 and large=0.8) or power (for p<0.05, effect size was calculated and for p>0.05 power of the test was calculated with Cohen's d)

TABLE 3. BETWEEN-GROUP COMPARISONS OF OUTCOME MEASURES

PARAMETERS	COMPARISON GROUPS		MEAN DIFFERENCE*	P*
HORIZONTAL VOR ASYMMETRY	CVR+WBV	CVR	9.33	0.063
	CVR+WBV+GVS	CVR	10.74	0.063
	CVR+WBV+GVS	CVR +WBV	1.41	1.000
ANTERIOR VOR ASYMMETRY	CVR+WBV	CVR	0.73	1.000
	CVR+WBV+GVS	CVR	0.45	1.000
	CVR+WBV+GVS	CVR+WBV	0.28	1.000
POSTERIOR VOR ASYMMETRY	CVR+WBV	CVR	1.75	0.346
	CVR+WBV+GVS	CVR	2.79	0.065
	CVR+WBV+GVS	CVR+WBV	1.03	0.340
JPS ERROR	CVR+WBV	CVR	0.93	<0.001
	CVR+WBV+GVS	CVR	0.94	<0.001
	CVR+WBV+GVS	CVR+WBV	0.01	1.000
ML DISPLACEMENT	CVR+WBV	CVR	5.46	<0.001
	CVR+WBV+GVS	CVR	14.53	<0.001
	CVR+WBV+GVS	CVR+WBV	9.06	<0.001
AP DISPLACEMENT	CVR+WBV	CVR	6.06	<0.001
	CVR+WBV+GVS	CVR	11.66	<0.001
	CVR+WBV+GVS	CVR+WBV	5.60	<0.001
LOS	CVR+WBV	CVR	9.93	<0.001
	CVR+WBV+GVS	CVR	15.93	<0.001
	CVR+WBV+GVS	CVR+WBV	6.00	<0.001
DHI SCORE	CVR+WBV	CVR	14.26	<0.001
	CVR+WBV+GVS	CVR	21.33	<0.001
	CVR+WBV+GVS	CVR+WBV	7.06	0.059

VOR; vestibulo-ocular gain, JPS; joint position sense, ML; mediolateral, AP: anterior-posterior, LOS; limit of stability, DHI; dizziness handicap inventory; CVR; conventional vestibular rehabilitation, WBV; whole body vibration, GVS; galvanic vestibular stimulation. Bold numbers: p<0.05, * bonferroni one-way ANOVA.