Research Article

Comparative Efficacy of Vestibular Rehabilitation, Noisy Galvanic Vestibular Stimulation, and Their Combination on Postural Control, Dizziness, Anxiety, and Depression in Patients with Persistent Postural-Perceptual Dizziness

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Short running title: Comparative Efficacy of Vestibular…

Highlights:

- VRT and GVS improved dizziness, anxiety, and depression in PPPD patients
- Combining nGVS with VRT showed no added benefits for postural control in PPPD
- Psychological improvements correlated with perceived postural control in PPPD

ABSTRACT

Background and Aim: Persistent Postural-Perceptual Dizziness (PPPD) is a chronic vestibular disorder characterized by persistent dizziness, non-spinning vertigo, or unsteadiness exacerbated by moving visual stimuli and upright postures. Vestibular Rehabilitation Therapy (VRT) has shown favorable outcomes. While noisy Galvanic Vestibular Stimulation (nGVS) has been associated with improvements in various psychiatric and neurological conditions, its efficacy in PPPD remains unclear. This study aimed to assess the effectiveness of

VRT, nGVS, and their combination on patients with PPPD in terms of postural control, dizziness, anxiety, and depression.
Methods: Twenty-seven patients diagnosed with PPPD were randomly assigned to three groups receiving treatment for six weeks: 1) VRT, 2) GVS, and 3) VRT+GVS. Outcome measures included static postural control parameters, Dizziness Handicap Inventory (DHI), and Hospital Anxiety and Depression Scale (HADS) scores.
Results: All groups demonstrated significant improvements in subjective measures (DHI and HADS) following treatment. Postural control improvements were observed only in specific conditions within each group, with no overall significant differences between the groups except for Mediolateral (ML) path length with eyes closed on a soft surface. Significant correlations were observed between improvements in postural control outcomes and questionnaire scores within each group.
Conclusion: VRT and GVS, both individually and in combination, were effective in subjective measurements but had minimal impact on static postural control. Adding nGVS to VRT did not provide additional benefits for PPPD patients. The correlations between postural control and psychological outcomes suggest that improvements in perceived dizziness, anxiety, and depression may be linked to postural stabilization.
Trial Registration Number: The study was registered in the Iranian Registry of Clinical Trials on 18 September 2023 (IRCT20160131026279N6).
Keywords: Persistent postural-perceptual dizziness; vestibular rehabilitation; galvanic vestibular stimulation; anxiety; depression

Introduction

Persistent Postural-Perceptual Dizziness (PPPD) is a complex functional vestibular disorder characterized by persistent dizziness, non-spinning vertigo, or unsteadiness, which worsens with moving visual stimuli and the patient's upright posture [1]. There are no specific epidemiological data available for PPPD. However, based on reports on phobic postural vertigo, chronic subjective dizziness, and visual vertigo, the prevalence of PPPD is estimated to be 15–20% among patients with vestibular symptoms, making it the second most common diagnosis [1-3]. The age range of affected individuals spans from adolescence to late adulthood [1], with an average age in the mid-40 s and a predominance of females [1, 3]. The incidence of PPPD is estimated to be 25% in patients with acute or chronic vestibular syndrome [1-3].

PPPD patients experience varying degrees of disability, ranging from minor difficulties in everyday functioning to complete inability to work [1-3]. The condition is diagnosed based on medical history and the Barany Society criteria. While physical examinations, laboratory tests, and neuroimaging are not used to diagnose PPPD directly, they are employed to identify coexisting conditions [1].

Review studies have shown that a significant proportion of PPPD patients do not experience substantial improvement with standard therapies, which typically include medication and behavioral psychotherapy. However, treatments such as vestibular rehabilitation, serotonergic antidepressants, and cognitive-behavioral therapy have been shown to yield favorable outcomes [2, 3]. The management of PPPD through Vestibular Rehabilitation Therapy (VRT) involves adaptation, substitution, and habituation techniques. These include self-induced motion and/or environmental stimuli motion that systematically induces dizziness. Physical exercises and training consist of postural control exercises, gait stabilization, conditioning activities, occupational retraining, coordination training, and exercises for gaze stabilization, all of which have demonstrated beneficial effects for PPPD patients. VRT helps restore balance, reduce falls, and minimize vertigo symptoms [4-11].

In recent years, the use of Galvanic Vestibular Stimulation (GVS) to stimulate the vestibular system in both health and disease has gained popularity. Noisy GVS (nGVS) is recognized as a highly effective and targeted vestibular stimulus that modulates the motor functions governed by the vestibular system, including the Vestibulo-Ocular (VOR) and vestibule spinal reflexes [12, 13]. Studies in healthy individuals have demonstrated that GVS enhances dynamic walking [12], as well as postural [14] and locomotor stability [15]. In humans standing quietly, the net effect of noisy GVS (nGVS) is postural adjustment, creating the sensation of body sway [16, 17]. Additionally, emerging evidence indicates that nGVS can stabilize static balance [18, 19], enhance vestibulospinal function [20, 21], and improve gait performance in patients with bilateral vestibulopathy [22, 23]. Synergistic effect of low-amplitude nGVS with physical vestibular rehabilitation accelerates static and dynamic vestibular compensation after unilateral vestibulopathy and improvs VOR and postural control in these patients [24]. Limited studies have investigated its effectiveness for PPPD [25, 26]. Given the demonstrated efficacy of nGVS in addressing balance disorders, the combined application of direct vestibular nerve stimulation and physical vestibular exercises may offer a synergistic approach, potentially amplifying the therapeutic outcomes for patients with PPPD. Therefore, the goal of this study was to determine whether the application of nGVS during VRT promotes better overall recovery compared to rehabilitation alone in patients with PPPD.

Methods

Participants

Participants were patients diagnosed with PPPD according to the diagnostic criteria set by the Barany Society Committee [1] referred to Al-Basra Educational Hospital, Iraq. The inclusion criteria consisted of individuals aged 18 to 65 years who had no previous experience with vestibular exercises or rehabilitation, no history of drug or alcohol addiction, no current neurological disorders, no consumption of drugs that suppress vestibular system compensation, were not pregnant, had no current coexisting vestibular diseases with PPPD, had no musculoskeletal disorders that impair gait, had no cognitive impairment, and had no vestibular paroxysmia. Patients who did not meet any of the inclusion criteria, such as experiencing fatigue or being unwilling to continue the test, were excluded from the study. A total of 27 participants met the requirements for participation and provided their informed consent.

All patients underwent a series of tests, including otoscopy, pure tone audiometry, immittance acoustic measurement, videonystagmography, and the video head impulse test, all of which showed normal results. Additionally, the modified Clinical Test of Sensory Interaction on Balance (mCTSIB), Arabic versions of the Dizziness Handicap Inventory (DHI) [27], and the Hospital Anxiety and Depression Scale (HADS) [28] were also administered. Patients were then randomly assigned into three groups, with nine patients in each group. The VRT group received vestibular rehabilitation for six weeks, the GVS group received nGVS (30 minutes, one session per week for six weeks), and the VRT+GVS group received VRT for six weeks combined with nGVS (30 minutes, one session per week for six weeks). Questionnaires and the mCTSIB were re-evaluated after treatment.

The mCTSIB test includes two 20-second trials designed to assess a patient's ability to control body sway under varying sensory conditions. During each trial, patients stood as still as possible on a balance forceplate (BTracking Balance System, USA), with hands on hips and feet shoulder-width apart. A tone signaled the start and end of each trial. Sensory feedback was altered by instructing patients to either close their eyes or stand on foam, with the following conditions: condition 1 (eyes open, hard surface), condition 2 (eyes closed, hard surface), condition 3 (eyes open, soft surface), and condition 4 (eyes closed, soft surface). Center of Pressure (COP) data were collected from the forceplate at a sampling rate of 25 Hz over 20 seconds of quiet standing. Data were processed using MATLAB (The MathWorks, MA, version 7.7.0471), utilizing a zero-lag, second-order Butterworth low-pass filter with a 4 Hz cutoff. Anterior-Posterior (AP) and Mediolateral (ML) path lengths of the COP, mean velocity in both directions, and Total Mean Velocity (TMV) were calculated for each trial.

The DHI is a 25-item self-assessment scale designed to evaluate the self-perceived handicap caused by dizziness across three subscales: functional, emotional, and physical difficulties. Answers are graded on a scale of 4 for "yes", 2 for "sometimes", and 0 for "no". Scores on the DHI range from 0 (no handicap) to 100 (significant perceived handicap). The Arabic version of the DHI was administered pre- and post-treatment [16].

The HADS is widely used to predict and diagnose anxiety and depression. We used the Arabic version, which consists of 14 questions: 7 for anxiety and 7 for depression. Each question is graded from 0 to 3. Scores from 8 to 10 indicate mild symptoms, 11 to 14 suggest moderate symptoms, and 15 or higher indicate severe symptoms [17].

Vestibular rehabilitation therapy consisted of home exercises performed for 30 minutes, twice a day, for six weeks. We maintained contact with the patients through WhatsApp and scheduled visits to the Audio-vestibular Department in the hospital every two weeks to monitor progress, provide education, and emphasize exercises deemed most beneficial. Exercises included gaze stabilization (VOR adaptation and substitution), habituation, and gait stabilization exercises.

Noisy GVS was provided by the Neurostim 2 electric current generator (Medina Teb Co., Iran), with a random bandwidth of less than 30 Hz, bipolar current with the anode electrode on the right and the cathode electrode on the left mastoid, and sub-threshold intensity. Patients were seated on a chair with their eyes closed. The threshold was obtained by slowly increasing the current intensity in 0.1 mA steps until the person reported itching or a burning sensation in the mastoid area where the electrode was placed, after which the current was decreased by 0.1 mA. The nGVS current was introduced 30 minutes weekly for six weeks.

Statistical analysis

The statistical analysis was conducted using SPSS V.26. Data were reported as mean±standard deviation. The normality of data distribution was assessed using the Kolmogorov-Smirnov test.

For within-group comparisons of pre- and post-intervention outcomes, paired t-tests were used for normally distributed data, and the Wilcoxon test was used for non-normally distributed data. To compare the level of improvement across outcomes between groups, ANOVA tests were used. The Tukey post hoc test was employed to assess significant differences between pairs of group means. To determine the correlation between improvements in anxiety, dizziness, and postural control outcomes within each group, Pearson/Spearman correlation tests were used. All confidence intervals were set at 95%, and a p-value<0.05 was considered statistically significant.

Results

The age range for participants was 18 to 57 years. The mean age was 32.44±10.82 years in the VRT group, 33.22±9.96 years in the VRT+GVS group, and 38.00±13.13 years in the GVS group. The gender distribution in the GVS and VRT groups was 77.8% females and 22.2% males. In the VRT+GVS group, the distribution was 66.7% females and 33.3% males. Differences in age and gender between groups were insignificant (p>0.5).

At the beginning of the study, there were no statistically significant differences between groups regarding outcome measures of mCTSIB, HADS, and DHI (p>0.05).

Within-group comparisons

In the VRT group, significant improvements were observed between pre- and post-treatment measurements for ML path length with eyes closed on a soft surface, AP velocity with eyes open on a hard surface, and TMV with eyes closed on a soft surface. In the GVS group, significant improvements were found in AP path length with eyes open on a soft surface, AP velocity with eyes closed on a hard surface, AP velocity with eyes open on a soft surface, AP velocity with eyes closed on a soft surface, ML velocity with eyes open on a soft surface, ML velocity with eyes closed on a soft surface, TMV with eyes open on a hard surface, and TMV with eyes closed on a soft surface. No other postural control outcome measures showed significant differences between pre-and post-treatment in either group (p>0.05; power≤0.58). Descriptive data are presented in Table 1.

Between-group comparisons

Between-group comparisons revealed significant differences in ML path length with eyes closed on a soft surface ($F_{(2,24)}$=4.135, p=0.029). The Tukey post hoc test showed a significant difference between the VRT and VRT+GVS groups (10.5±2.3 vs. 6.4±2.1; 95% confidence interval: 0.01 to 8.11; p=0.042), indicating greater improvement in the VRT group. No significant differences were observed between the groups for other parameters (p>0.05; power ≤0.49). Figure 1 presents box plots illustrating changes in ML and AP path length, velocity, and TMV under the four different conditions, pre- and post-treatment.

Questionnaire findings

All three interventions significantly improved the functional, emotional, and physical aspects measured by the DHI and reduced anxiety and depression scores as measured by the HADS (Table 2). The VRT+GVS group generally showed the most substantial improvements, followed by the GVS group, and then the VRT group. However, ANOVA did not show significant differences between groups for the DHI, HADS, or any of their subscales (p>0.05).

Correlation analysis

Correlation analysis for mean improvements in various parameters within each group revealed several noteworthy findings. In the VRT group, significant correlations were observed between DHI physical score and ML path length of the COP with eyes open on a soft surface (ρ=0.73, p=0.03) and AP path length with eyes closed on a hard surface (r=0.68, p=0.04). The DHI total score showed significant correlations with ML path length of the

COP with eyes open on a soft surface (ρ=0.73, p=0.02) and AP path length with eyes closed on a hard surface (r=0.77, p=0.01).

In the GVS group, significant correlations were found between the DHI physical score and velocity of the COP in the ML direction with eyes open on a soft surface (ρ=–0.79, p=0.012) and TMV with eyes open on a soft surface (r=–0.77, p=0.016). Significant correlations were also observed between HADS anxiety score and ML path length of the COP with eyes open on a soft surface (r=0.84, p=0.001), AP velocity with eyes open on a hard surface (r=–0.76, p=0.018), AP velocity with eyes closed on a hard surface (r=–0.88, p=0.002), TMV with eyes open on a hard surface (r=–0.73, p=0.025), and TMV with eyes open on a soft surface (r=–0.80, p=0.009). There were also significant correlations between HADS total score and ML path length (r=0.78, p=0.01), velocity (ρ=–0.77, p=0.016), and TMV (r=–0.823, p=0.006), all with eyes open on a soft surface.

In the VRT+GVS group, the HADS depression score was significantly correlated with ML path length of the COP with eyes closed on a hard surface (r=0.69, p=0.04) and ML velocity with eyes open on a soft surface (r=0.78, p=0.014). No significant correlations were found between mCTSIB outcome measures and DHI or HADS total and subscale scores in any of the groups or the total sample (p>0.5).

Discussion

The present study aimed to explore the effects of VRT combined with GVS, GVS alone, or VRT alone on postural control outcomes in patients with PPPD.

According to the findings, all groups showed significant improvements in DHI and HADS scores after the intervention, underscoring the efficacy of these interventions in managing vestibular disorders. This finding is consistent with previous studies that demonstrated home-based VRT could improve quality of life, dizziness handicap as assessed by DHI, and levels of depression and anxiety as measured by the Depression, Anxiety and Stress Scale –21 questionnaires [10]. These findings align with existing literature indicating that VRT enhances balance and reduces dizziness symptoms in patients with vestibular disorders. The emotional and physical improvements observed are consistent with reports suggesting that VRT can alleviate the psychological distress associated with vestibular dysfunction [29]. These findings highlight the psychological benefits of these interventions, particularly in reducing anxiety and depression symptoms related to vestibular disorders. Similarly, Choi et al. found that customized vestibular exercises using a virtual reality system improved dizziness, quality of life, and gait function in patients with PPPD. They reported significant improvements in DHI, activities of daily living, visual vertigo analogue scale, and timed up-and-go. However, there was no improvement in sensory organization test results [8]. In contrast, another study showed improvements in both DHI and sensory organization test results after VRT games in PPPD patients [11].

In terms of postural control analysis, our findings showed improvement only in ML path length of the COP with eyes closed on a soft surface in the VRT group, a condition where patients primarily rely on the vestibular system. This signifies enhanced balance control in conditions that stress the vestibular system. This finding aligns with previous research suggesting that VRT effectively improves postural stability, particularly in conditions requiring high sensory integration [30]. In contrast, the GVS group showed significant improvements in AP path length of the COP with eyes open on a soft surface, and velocity outcome measures, mostly on soft surfaces. This is not in agreement with Woll et al., who found no effect of nGVS on postural control in PPPD patients. They also reported low GVS-evoked perception thresholds for body motion in PPPD patients and noted differences in performance across simple and complex balance tasks (eyes closed vs. open) [25]. This suggests that GVS's effects may be more pronounced in tasks with combined challenges, such as a soft surface and visual input, highlighting the context-specific nature of the intervention's efficacy. The absence of significant differences in other sway parameters indicates that while all interventions may contribute to balance improvements, their specific effects vary depending on the conditions and the nature of the sway being measured. GVS may enhance postural control by providing additional sensory input that helps stabilize balance. Similar findings have been reported in studies highlighting GVS's potential to improve postural stability in patients with vestibular disorders [24, 31]. Our study found that other mCTSIB outcomes did not significantly change following interventions, which may be due to several factors. First, we did not have a normal group for comparison to healthy individuals, which could have improved the interpretation of the results. Second, PPPD is a functional (psychological) disorder where the brain overreacts or mishandles information, which may not be detectable with mCTSIB. Third, our patients showed improvements in dynamic balance based on DHI, quality of life, and reduced phobia from recurrent attacks. Therefore, dynamic objective measures like the Dynamic Gait Index (DGI) or dynamic posturography may be more suitable than static measures like mCTSIB. In addition, the GVS protocol, including intensity, electrode montage, and the type of stimulation (e.g. noisy vs direct current), should be considered an important factor. Double temple-mastoidal stimulation has been shown to induce greater changes in body sway in healthy individuals [16]. We also found significant relationships between postural control parameters and psychological measures within each group. These correlations underscore the importance of considering both physical and psychological factors in assessing the effectiveness of vestibular interventions [32]. The significant correlations between anxiety and depression and postural control outcomes in these groups further emphasize the need for comprehensive treatment approaches that address both balance and psychological status.

Although all groups showed improvement after the intervention compared to before, there were no significant differences between groups in terms of DHI, HADS, and postural control outcomes, except for ML path length of the COP with eyes closed on a soft surface. The observed powers were low. This finding suggests that combining nGVS with VRT may not lead to additive or synergistic effects, contrary to our expectations. To our knowledge, no previous studies have investigated the impact of combining GVS and VRT specifically for PPPD. Some studies examining simultaneous use in other vestibular disorders have reported improved outcomes [24], while others did not show synergistic effects [33]. The lack of synergistic effects between nGVS and VRT may be attributed to the limited number and duration of sessions, as well as the non-simultaneous delivery of nGVS and VRT, which may have been insufficient to produce significant improvements. nGVS was administered once a week in the clinic, while patients performed vestibular exercises at home. Alternatively, it is possible that stimulating the vestibular receptors through GVS did not sufficiently influence higher-order processes involved in PPPD, such as sensory integration at the brainstem and cerebellar levels. Due to the low observed power, the lack of significant differences within and between groups can be attributed to the low sample size as well.

The clinical implications of our study challenge previous research demonstrating the effectiveness of vestibular rehabilitation in improving balance control. However, our findings extend the current understanding by emphasizing the importance of integrating psychological support into rehabilitation programs, addressing both the physical and psychological aspects of vestibular disorders for more comprehensive treatment outcomes. Integrating psychological support in vestibular rehabilitation aligns with the biopsychosocial model of healthcare, emphasizing the importance of addressing psychological and social factors in addition to the biological aspects of illness [34]. Studies have shown that psychological factors, such as anxiety and depression, can significantly impact the perception of dizziness and balance control [35, 36]. By addressing these psychological factors alongside physical therapy, clinicians can provide more holistic care and improve overall treatment outcomes for individuals with vestibular disorders. Furthermore, integrating psychological support in vestibular rehabilitation may also enhance treatment adherence and satisfaction. Studies have shown that patients are more likely to adhere to treatment plans when they feel supported and understood by their healthcare providers [37].

Conclusion

In conclusion, the interventions demonstrated that Vestibular Rehabilitation Therapy (VRT) and Galvanic Vestibular Stimulation (GVS), both individually and in combination, were effective in improving subjective measurements. However, they had minimal impact on postural control. Additionally, adding GVS to VRT did not show a significant improvement in outcomes for persistent postural-perceptual dizziness patients. Significant correlations were found between balance parameters and various psychological and functional scores, suggesting that improvements in balance were linked to reductions in perceived dizziness, anxiety, and depression. The observed powers for non-significant findings were low. Further studies are required to explore these findings in more depth.

Ethical Considerations

Compliance with ethical guidelines

This study was a randomized controlled trial approved by the Ethics Committee of Tehran University of Medical Sciences (Code IR.TUMS.FNM.REC.1402.124) and registered in the Iranian Registry of Clinical Trials (Reference Number IRCT20160131026279N6). Participants were informed about the aim of the study, and written consent was obtained.

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Authors' contributions

SSAA: Acquisition of data, drafting the manuscript, analysis, and interpretation of data; MAG: Study concept and design, study supervision, drafting/critical revision of the manuscript for important intellectual content; ET: Study advising, drafting/critical revision of the manuscript for important intellectual content; SJ: Statistical analysis, critical revision of the manuscript for important intellectual content; KM: Analysis and interpretation of data, critical revision of the manuscript for important intellectual content; AA: Critical revision of the manuscript for important intellectual content.

Conflict of interest

There are no competing interests declared by the authors

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Table 1. Mean (standard deviation) of anterior-posterior and mediolateral path lengths, mean velocities, and total mean velocity of center of pressure before and after treatment across three groups

		VRT group (n=9)			GVS group (n=9)			VRT+GVS group (n=9)		
		Before	After		Before	After		Before	After	
Outcome	**Condition**	**Mean(SD)**	**Mean(SD)**	**p**	**Mean(SD)**	**Mean(SD)**	**p**	**Mean(SD)**	**Mean(SD)**	**p**
ML path length	**Eyes open on hard surface**	3.40(3.21)	5.01(2.52)	NS*	2.18(2.25)	1.422(1.09)	NS*	2.62(2.22)	2.88(2.48)	NS*
	Eyes closed on hard surface	4.84(5.53)	5.51(3.58)	NS*	1.92(2.13)	1.34(1.14)	NS*	2.39(1.30)	1.73(1.56)	NS*
	Eyes open on soft surface	4.00(3.20)	5.14(2.65)	NS*	2.96(2.11)	2.52(1.98)	NS*	4.33(4.44)	2.82(1.36)	NS*
	Eyes closed on soft surface	11.74(6.99)	6.99(4.31)	0.032†	2.77(1.45)	2.13(1.13)	NS*	4.62(2.18)	3.68(1.59)	NS*
AP path length	**Eyes open on hard surface**	4.14(3.24)	5.51(3.18)	NS*	3.27(2.38)	2.53(1.54)	NS*	3.04(1.14)	2.69(1.24)	NS*
	Eyes closed on hard surface	5.96(5.62)	4.34(3.33)	NS*	3.60(2.13)	2.19(1.44)	NS*	4.36(4.07)	2.76(0.73)	NS*
	Eyes open on soft surface	5.43(3.81)	4.49(1.60)	NS*	5.46(2.17)	2.86(1.27)	0.006†	4.14(1.60)	3.58(1.45)	NS*
	Eyes closed on soft surface	8.78(4.75)	7.58(3.07)	NS*	6.16(3.18)	3.77(1.97)	NS*	6.19(2.37)	6.04(3.65)	NS*
ML velocity	**Eyes open on hard surface**	1.15(0.70)	0.67(0.24)	NS*	0.75(0.40)	0.62(0.19)	NS*	0.99(0.48)	0.84(0.41)	NS*
	Eye closed on hard surface	1.35(0.87)	0.82(0.24)	NS*	1.03(0.98)	0.57(0.19)	NS*	1.28(0.77)	1.24(0.87)	NS*
	Eyes open on soft surface	1.64(0.84)	0.99(0.38)	NS*	1.02(0.45)	0.61(0.20)	0.014†	1.59(0.49)	1.53(0.95)	NS*
	Eyes closed on soft surface	2.70(1.32)	2.04(1.05)	NS*	1.67(0.75)	0.84(0.62)	0.012†	2.72(1.15)	2.34(1.47)	NS*
AP velocity	**Eyes open on hard surface**	1.13(0.45)	0.70(0.25)	0.049†	0.71(0.41)	0.47(0.21)	NS*	1.11(0.60)	0.97(0.43)	NS*
	Eye closed on hard surface	1.08(0.81)	0.74(0.40)	NS*	0.87(0.48)	0.39(0.20)	0.008‡	1.31(1.03)	1.25(0.56)	NS*
	Eyes open on soft surface	1.30(0.85)	0.85(0.27)	NS*	0.81(0.32)	0.49(0.20)	0.015‡	1.37(0.46)	1.12(0.53)	NS*
	Eyes closed on soft surface	1.95(1.21)	1.15(0.48)	NS*	1.12(0.75)	0.51(0.27)	0.008‡	1.95(1.21)	1.15(0.48)	NS*
TMV	**Eyes open on hard surface**	1.81(0.91)	1.18(0.36)	NS*	1.17(0.62)	0.87(0.28)	NS*	1.65(0.84)	1.46(0.62)	NS*
	Eye closed on hard surface	1.94(1.34)	1.25(0.47)	NS*	1.54(1.53)	0.77(0.28)	NS*	2.06(1.42)	2.04(1.10)	NS*
	Eyes open on soft surface	2.35(1.27)	1.46(0.46)	NS*	1.46(0.53)	0.89(0.25)	NS*	2.33(0.67)	2.10(1.19)	NS*
	Eyes closed on soft surface	3.76(1.90)	2.56(1.20)	0.035†	2.34(1.16)	1.10(0.71)	0.003‡	4.07(2.04)	3.12(1.79)	NS*

VRT; vestibular rehabilitation therapy, GVS; galvanic vestibular stimulation, ML; mediolateral, AP; anterior-posterior, TMV; total mean velocity

* Not significant; power ≤ 0.58, † Paired t-test, ‡ Wilcoxon test

Table 2. Within-group comparisons of Arabic versions of dizziness handicap inventory and hospital anxiety and depression scale scores

		VRT group (n=9)			GVS group (n=9)			VRT+GVS group (n=9)		
		Before	After		Before	After		Before	After	
Questionnaire	Score	Mean(SD)	Mean(SD)	p	Mean(SD)	Mean(SD)	p	Mean(SD)	Mean(SD)	p
DHI	Functional	27.33(7.87)	20.22(9.97)	0.031	24.00(6.85)	15.11(6.17)	0.010	23.77(6.00)	12.66(6.00)	0.003
	Emotional	26.20(10.55)	18.00(13.19)	0.013	20.44(7.98)	13.55(6.76)	0.008	27.11(9.11)	16.44(11.17)	0.004
	Physical	22.88(7.88)	11.50(8.26)	0.025	16.00(4.89)	7.33(4.24)	0.000	18.66(7.00)	10.88(7.14)	0.018
	Total	74.22(18.26)	50.44(29.37)	0.003	59.33(18.35)	36.00(14.10)	0.000	69.55(22.75)	38.88(18.73)	0.000
HADS	Anxiety	14.00(6.32)	9.22(6.37)	0.005	10.11(3.55)	4.55(2.35)	0.000	13.88(3.75)	8.22(2.94)	0.001
	Depression	11.00(4.35)	8.55(5.27)	0.038	10.00(2.54)	6.22(2.94)	0.020	9.66(3.39)	6.22(2.43)	0.009
	Total	25.00(9.02)	17.77(11.07)	0.005	20.11(5.48)	10.77(5.01)	0.001	23.55(6.18)	14.44(4.87)	0.001

VRT; vestibular rehabilitation therapy, GVS; galvanic vestibular stimulation, DHI; dizziness handicap inventory, HADS; hospital anxiety and depression scale

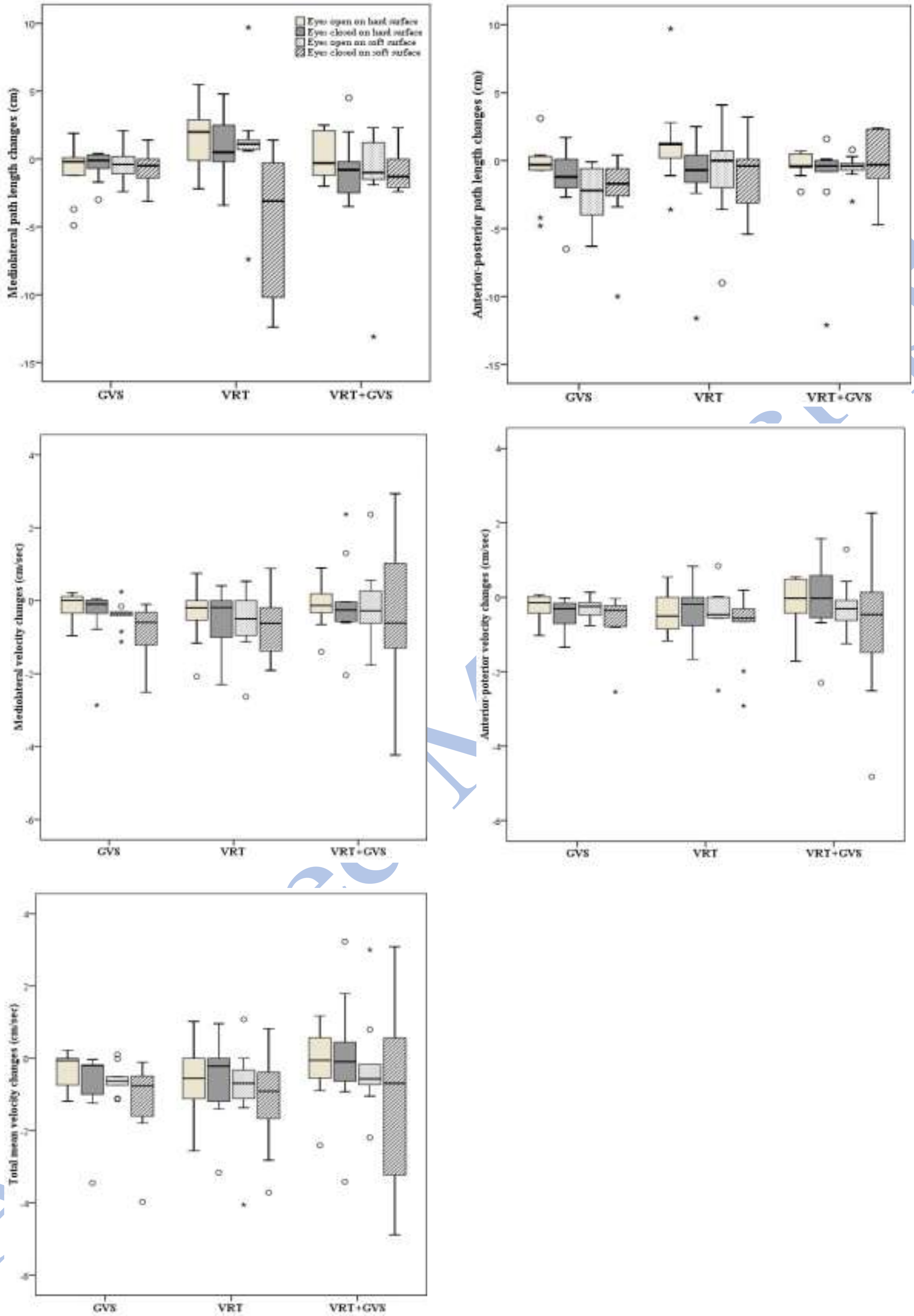

Figure 1. Median, minimum, and maximum changes of mediolateral and anterior-posterior path length and velocity, and total mean velocity of the center of pressure in four conditions in three groups. GVS; galvanic vestibular stimulation, VRT; vestibular rehabilitation therapy