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Original Article

The Value of Vestibular Rehabilitation in Patients with Bilateral Vestibular Dysfunction

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OBJECTIVE: The value of vestibular rehabilitation in patients with bilateral vestibular dysfunction was investigated.

MATERIALS and METHODS: This study assessed 17 patients (9 males, 8 females) with bilateral vestibular dysfunction. Vestibular rehabilitation continued for 1.5 months. Videonystagmography tests (including oculomotor testing, positional testing, and caloric tests), vestibular evoked myogenic potential (VEMP) testing, and computerized dynamic posturography were performed during the pre-, mid-, and post-treatment periods. The patients underwent cranial and internal acoustic canal MRI. Consultant physicians from the neurology and physical medicine and rehabilitation departments reviewed all patients.

RESULTS: The post-treatment anteroposterior somatosensorial (APSO), anteroposterior global (APGLO), mediolateral visual (MLVI), and mediolateral global values and anteroposterior and mediolateral trials and conditions were significantly higher than those measured in the pre-treatment period. Similarly, mid-treatment values of the APSO, APGLO, and the anteroposterior sensory organization test (SOT) 2 were significantly higher than those measured in the pre-treatment period.

CONCLUSION: Vestibular rehabilitation was effective in patients with bilateral vestibular dysfunction. As the vestibular rehabilitation duration increased, so did the efficacy of the treatment.

KEYWORDS: Bilateral vestibular dysfunction, computerized dynamic posturography, vestibular rehabilitation, videonystagmography, sensory organization test

INTRODUCTION

Dizziness and vertigo are frequently encountered symptoms in patients admitted to a physician. Dizziness can manifest itself by falling that is a more likely scenario in elderly with other neurological diseases [1].

The incidence of dizziness, vertigo, and imbalance is approximately 40% in patients over 40 years. The incidence of falling is observed in nearly 25% of patients over 65 years. 2.5% of all patients admitted to US emergency departments (EDs) between 1995 and 2004 suffered from vertigo and dizziness [2].

Tailored exercises for vestibular rehabilitation ensure the coordination between the vestibule-ocular reflexes, vestibule-spinal reflexes [1]. In a study in which 26 patients admitted to ED with benign paroxysmal positional vertigo was presented; no difference was observed with respect to nausea or dizziness between vestibular rehabilitation (15 patients) and medical treatment (11 patients). Both groups were satisfied and the time of stay in ED did not differ between them [3].

In this study, we investigated the role of vestibular rehabilitation in patients with bilateral vestibular dysfunction by comparing vestibular, visual, somatosensory, preferential, and global scores, and Romberg's quotient, in the sensory organization test (SOT). Patients with bilateral vestibular dysfunction underwent vestibular rehabilitation for 1.5 months. Videonystagmography (VNG), vestibular evoked myogenic potential (VEMP) testing, and computerized dynamic posturography (CDP) were performed during the pre-, mid-and post-treatment periods.

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MATERIALS and METHODS

This prospective study was conducted at the Otorhinolaryngology Department of Bayındır Hospital between January 2015 and April 2016. The study followed the tenets of the Declaration of Helsinki. The informed consent was obtained from all patients.

Subjects

In total, 17 patients (9 males, 8 females) with bilateral vestibular dysfunction were assessed. Their mean age was 70.2±12.6 (range, 51.0-91.0) years. VNG tests (including oculomotor testing, positional testing, and caloric tests), VEMP testing, and CDP were performed in the pre-, mid-,and post-treatment periods. The patients underwent cranial and internal acoustic canal MRI. All patients were reviewed by consultant physicians the neurology and physical medicine and rehabilitation departments. Vestibular rehabilitation continued for 1.5 months.

Posturography Test Procedure

All patients completed the six standardized sensory conditions of the SOT according to the manufacturer's instructions [4]. Cohen et al. [5] summarizes the test conditions. The SOT enables comparison of vestibular, visual, somatosensory, preferential, and global scores, and Romberg's quotient. These components were calculated from the results of the SOT and of a second test outlined in the following sections.

Somatosensorial score = Condition 1/Condition 2

This eliminates the visual input and does not stimulate vestibular input (static platform). This score represents the patient's ability to use somatosensorial input.

Visual Score= Condition 4/Condition 1

This score shows the patient's ability to use visual input. The somatosensorial input is eliminated due to the unstable platform of condition 4. In addition, the patients keep their eyes open and use vision to maintain balance, because vestibular information is non-existent in comparison with the visual information.

Vestibular score= Condition 5/Condition 1

The somatosensorial input is eliminated by going from a stable base to an unstable base and the visual input is eliminated by the visual condition"eyes closed". This score represents the patient's ability to use vestibular input.

Preferential Score = Condition 3 + Condition 6 / Condition 2 + Condition 5

This score evaluates the patient's ability to ignore erroneous visual information to maintain balance. In conditions 3 and 6, visual information is available but erroneous, so the patient must ignore this and instead rely on proprioceptive (Condition 3) or vestibular (Condition 6) information.

Global Score

The Global Score is an overall score that incorporates all conditions. This provides a general assessment of the patient's ability to use sensory input to maintain balance.

Romberg's quotient

Romberg's quotient (RQ) is the ratio, expressed as a percentage, of the surface of the statokinesigram (SKG) with the eyes closed to that on the surface of the SKG with the eyes open. This allows assessment of the role of the visual afferent systems in postural control, as well as its importance to and influence in other systems. This quotient, plotted with a horizontal-bar chart, is drawn in green if it is found in the reference time interval, and in red otherwise [4].

Statistical Analyses

Statistical Package for the Social Sciences (SPSS Inc.; Chicago, IL, USA) ver. 16.0 was used for the following statistical evaluations. The Kruskal-Wallis test was used to assay differences between the groups (pre-, mid-, and post-treatment). The specific statistically significant differences were determined by using the Wilcoxon signed-rank test with Bonferroni correction for pair-wise comparisons. A p-value <0.05 was accepted as statistically significant. For Bonferroni corrections, an adjusted p-value < 0.0175 was accepted as statistically significant.

The Number Cruncher Statistical System 2007 (Kaysville, UT, USA) was used for the following analyses. Changes in values of the SOT, the effects of sex, age, and SOT condition on these changes were analyzed by covariance analysis (repeated-measures ANCOVA). Pre-, mid-, and post-treatment measurements were within-subject factors, where as sex and SOT conditions were added as between-subject factors; age was evaluated as a covariate. A p-value < 0.05 was accepted as statistically significant.

RESULTS

Table 1 shows changes in values of the SOT, the effects of sex, age, and SOT condition on these changes. The results of the SOT in the pre-, mid-, and post-treatment periods analyzed in Table 2. Differences between SOT items at the three times were analyzed with the Kruskal-Wallis test. Significance was determined by the Wilcoxon signed-rank test with Bonferroni correction.

Table 1. Tests of within subjects effects

	F	p
AP		
Time	5.709	0.004*
Time * Age	2.626	0.075
Time * Gender	1.516	0.223
Time * SOT condition	1.773	0.068
Time * Gender * SOT condition	1.262	0.255
ML		
Time	8.597	<0.001*
Time * Age	5.977	0.003*
Time * Gender	3.993	0.020*
Time * SOT condition	1.672	0.090
Time * Gender * SOT condition	0.901	0.534

AP: anteroposterior; ML: mediolateral; SOT: sensory organization test

Outcomes of SOT (test, re-test values)

1. Anteroposterior (AP)

SOT1 values in the post-treatment period were significantly higher than in the pre- andmid-treatment periods (adjusted p<0.0175).

SOT2 values in the post- and mid-treatment periods were significantly higher than in the pre-treatment period (adjusted p<0.0175).

SOT5 values in the post-treatment period were significantly higher than in the pre-treatment period (adjusted p<0.0175).

2. Mediolateral (ML)

SOT4 values in the post-treatment period were significantly higher than in the pre- and mid-treatment periods (adjusted p<0.0175). Age-adjusted estimated mean SOT values (AP and ML) for each sex and time are shown in Figure 1.

Anteroposterior values

Changes in SOT values in the pre-, mid-, and post-treatment periods were found to be significant (F=5.709, p=0.004). Age and sex did not interact with SOT values (p>0.05; Table 3). The differences in SOT values between pre- and mid-treatment, pre- and post-treatment, and mid- and post-treatment were significant (p<0.001).

Table 2. The results of the SOT in the pre-, mid- and post-treatment periods

			95% Confidence Interval	
Time	**Mean**	**Std. error**	**Lower bound**	**Upper bound**
Pre-treatment	47.01	1.50	44.04	49.99
Mid-treatment	55.16	1.26	52.66	57.66
Post-treatment	59.43	1.12	57.20	61.67

SOT: sensory organization test; SD: standard

Mediolateral values

The changes in SOT values at the different times (the pre-, mid- and post-treatment periods) were found to be statistically significant (F=8.597, p<0.001). Age and sex significantly interacted with SOT values (F=5.977, p=0.003 and F=3.993, p=0.020, respectively; Table 4). In females, the difference between pre- and post-treatment (p<0.001) and between mid- and post-treatment (p=0.006) were significant. In males, the difference between mid- and post-treatment was significant (p<0.001). SOT values for the sex and SOT condition interaction (anteroposterior) are shown in Table 5.

The values of SOT1-6 differed in males and females (p=0.024). The mean SOT value was 51.36 in males and 56.37 in females. The mean

Table 3. Interaction of sex with SOT values in the pre-, mid- and post-treatment periods

				95% Confidence Interval	
Gender	**Time**	**Mean**	**Std. error**	**Lower bound**	**Upper bound**
Female	Pre-treatment	53.49	2.20	49.11	57.86
	Mid-treatment	57.35	1.81	53.74	60.95
	Post-treatment	62.73	1.36	60.02	65.44
Male	Pre-treatment	52.23	2.07	48.11	56.36
	Mid-treatment	48.42	1.71	45.02	51.81
	Post-treatment	55.71	1.29	53.15	58.26

SOT: sensory organization test

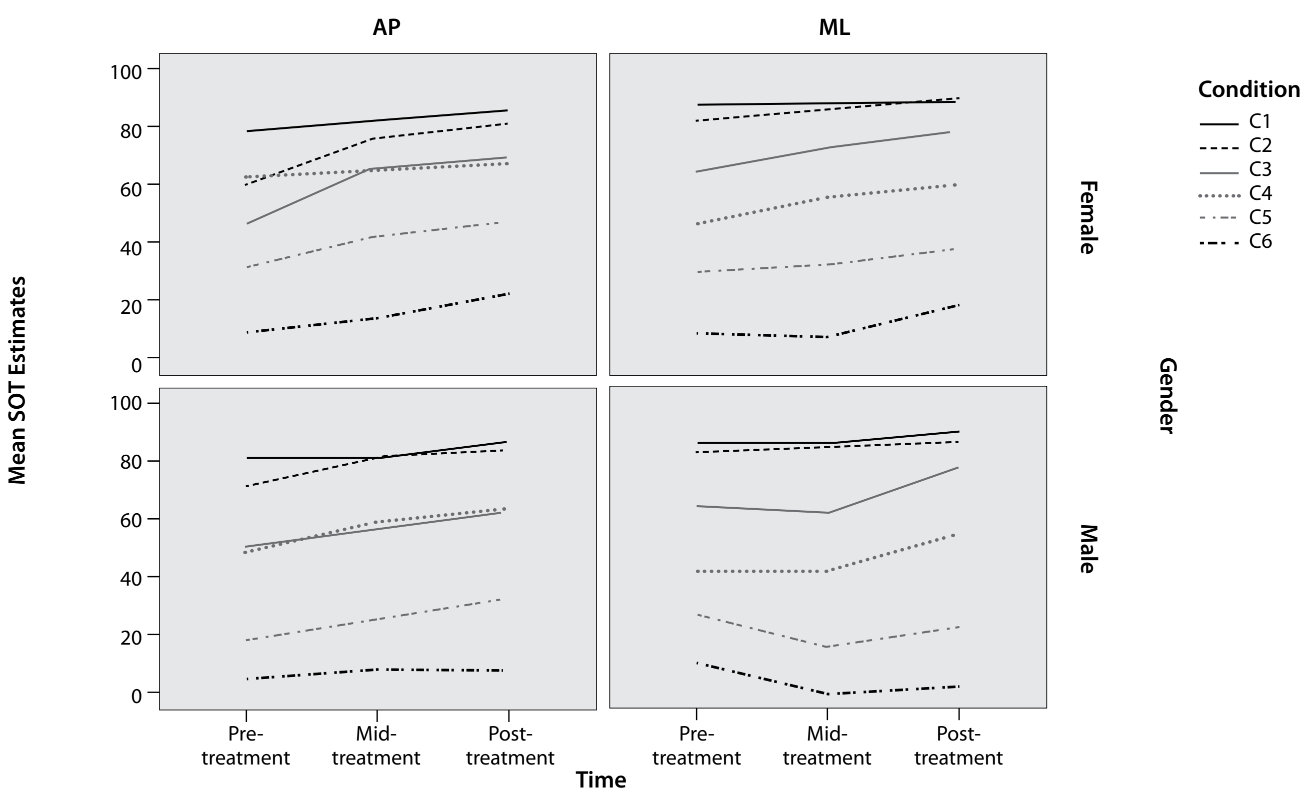

Figure 1. Age adjusted-estimated mean VNG (AP and ML) for each gender and time

Table 4. Tests of between subjects effects

	F	p
AP		
Intercept	88.504	<0.001*
Age	0.381	0.539
Gender	5.264	0.024*
SOT condition	101.914	<0.001*
Gender * SOT condition	1.949	0.094
ML		
Intercept	109.633	<0.001*
Age	0.030	0.864
Gender	9.061	0.003*
SOT condition	191.504	<0.001*
Gender * SOT condition	0.925	0.469

ML: mediolateral; SOT: sensory organization test; AP: anteroposterior

Table 5. Postulography values for gender and SOT condition interaction (anteroposterior)

				95% Confidence Interval	
Gender	Condition	Mean	Std. error	Lower bound	Upper bound
Female	C1	82.37	3.89	74.63	90.10
	C2	73.09	3.89	65.36	80.83
	C3	61.01	3.89	53.28	68.75
	C4	65.63	3.89	57.90	73.37
	C5	40.89	3.89	33.15	48.62
	C6	15.25	3.89	7.52	22.99
Male	C1	82.98	3.67	75.69	90.28
	C2	78.90	3.67	71.60	86.19
	C3	56.67	3.67	49.37	63.96
	C4	56.95	3.67	49.66	64.24
	C5	25.54	3.67	18.24	32.83
	C6	7.15	3.67	-.15	14.44

SOT: sensory organization test; Std: standard

SOT value was 82.68 for SOT1, 75.99 for SOT2, 58.84 for SOT3, 61.29 for SOT4, 33.21 for SOT5, and 11.20 for SOT6. There was no significant interaction between sex and SOT condition (p>0.05; Table 5).

SOT values for the sex and SOT condition interaction (mediolateral)

SOT values for the sex and SOT condition interaction (mediolateral) are shown in Table 6. The SOT values differed in males and females (p=0.003). The mean SOT values were 52.12 in males and 57.85 in females. SOT values varied according to the SOT condition (p<0.001). The mean SOT value was 87.84 for SOT1, 85.63 for SOT2, 70.24 for SOT3, 50.28 for SOT4, 27.85 for SOT5, and 8.08 for SOT6. The SOT interaction of sex and condition variable was not statistically significant (p>0.05; Table 6).

The values of anteroposterior somatosensorial (APSO) and anteroposterior global (APGLO) in the mid- and post-treatment periods were significantly higher than in the pre-treatment period (adjusted p<0.0175).The medialateral visual (MLVI) value in the post-treatment period was significantly higher than in the pre- and mid-treatment periods. The mediolateral global (MLGLO) value in the post-treatment period was significantly higher than in the mid-treatment period (adjusted p<0.0175).

Table 6. Postulography values for gender and SOT condition interaction (mediolateral)

				95% Confidence Interval	
Gender	Condition	Mean	Std. error	Lower bound	Upper bound
Female	C1	88.18	3.39	81.43	94.92
	C2	86.29	3.39	79.55	93.04
	C3	72.33	3.39	65.58	79.07
	C4	54.49	3.39	47.74	61.23
	C5	33.97	3.39	27.23	40.72
	C6	11.87	3.39	5.12	18.61
Male	C1	87.51	3.20	81.15	93.87
	C2	84.97	3.20	78.61	91.33
	C3	68.15	3.20	61.80	74.51
	C4	46.08	3.20	39.72	52.44
	C5	21.72	3.20	15.36	28.08
	C6	4.29	3.20	-2.07	10.65

SOT: sensory organization test; Std: standard

DISCUSSION

The two vestibular nuclei in the brainstem collect neural inputs from inner ear, neck muscles, the spinal cord, visual system, reticular formation and cerebellum. Eye movements, posture, autonomic response and forming sensations are the outputs of these vestibular nuclei. Commissural connections are utmost important in connecting the vestibular nuclei. The head movements are detected by the vestibular receptors in the inner ear which the generate corrective eye movements along with postural corrections to maintain stable visual image and gait. These responses are the outcome of an imbalance in neural activity between two vestibular nuclei produced by a simple head motion [6].

Vertigo is classified as either peripheral or central. Peripheral vertigo is about three-fourths of vestibular deficiencies. Benign paroxysmal positional vertigo (BPPV) is determined as the most common peripheral vestibular deficiency. BPPV is followed by Ménière's disease, vestibular neuritis, labyrinthitis, perilymphatic fistula, and acoustic neuroma. Central disorders like psychiatric disorders, multiple sclerosis, migraine, cerebrovascular disorders, tumors of the posterior fossa, cerebellar disease and neurodegenerative disorders can cause dizziness and vertigo [7].

Bilateral vestibulopathy is occurred after damage of balance organs in inner ears. It causes imbalance and visual symptoms called as oscillopsia [8]. Oscillopsia is also common during walking [9].

Computerized dynamic posturograhpy (CDP) is an assessment technique for analysing sensory, motor and central damages in vestibular organs [10]. SOT, which identifies balance disorders caused by vestibular, visual and somatosensory inputs, is a part of CDP. The limits of stability test in CDP measures the maximum angle of displacement of the center of gravity (CoG) from the central position two dimensionally [11]. The differences in the use of sensory input in various populations such as young children, older adults and patients with peripheral neuropathy, vestibular dysfunction and Parkinson's disease have been shown with the aid of SOT [12].

Vestibular rehabilitation therapy (VRT) is composed of specialized exercises which are used in stabilizing the gait. Head movements are the main exercises in VRT because of their importance in retraining and stimulating the vestibular system-Some of the studies found the customized VRT programs to be more effective than generic exercises [7]. VRT is effective in managing the imbalance related to the vestibular deficiency and central balance disorders [13]. The main principles of VRT are desensitization of the vestibular system, inducing the gain of vestibule-ocular /vestibule-spinal reflexes and creating new alternative senses against the imbalance disorders trigerred by the positional movements. All of these improving mechanisms can result in progressive recovering of dizziness and vertigo. Central nervous system (CNS) has a role in providing a stable posture through controling eye, head and body movements [7].

McDonnell and Hillier [14], depending on randomized and controlled studies, reported that VRT was an effective treatment method in resolving the symptoms and healing of unilateral peripheral vestibular deficiency.

The combination of reposition maneuvers and VRT for benign paroxysmal positional vertigo is more effective in long term than short term; however there is no evidence about which forms of VRT are effective. VRT rebuilds homeostasis within the vestibular system and this adaptation mechanisms ensure management of symptoms and a stable posture in a long term [7].

The home-based vestibular rehabilitation theraphy programs are customized for the patients. They do exercise at home several times a day individually and are followed up by the therapist in regular times until the balance disorder disappears. The VRT programs start at a minimum level that the patient is capable of and gradually increased to the level that optimum balance is obtained [7].

In this study, we investigated the outcomes of SOT (vestibular, visual, somatosensory, preferential, and global scores, and Romberg's quotient) in patients with bilateral vestibular dysfunction in the pre-, mid-, and post-treatment periods. We found that the post-treatment APSO, APGLO, MLVI, and MLGLO values, as well as various anteroposterior and mediolateral SOT values, were significantly higher than in the pre-treatment period. Similarly, the mid-treatment values of APSO and APGLO, and anteroposterior SOT 2, were significantly higher than in the pre-treatment period.

The mid- and post-treatment anteroposterior values of SOT were significantly higher than the pre-treatment values ($p<0.001$). Similarly, the post-treatment mediolateral values of SOT were significantly higher than the pre-treatment values ($p<0.001$). However, there was no significant improvement in the mid- versus pre-treatment mediolateral values of SOT ($p>0.05$). The mediolateral values of SOT showed significant differences by sex.

CONCLUSION

In this study, sensorial, visual and somatosensorial recovery in patients with bilateral vestibular dysfunction, which had been achieved after vestibular rehabilitation therapy, was determined by posturography. The recovery in imbalance symptoms was evaluated using the vestibular, visual, somatosensorial, preferential, and global scores and Romberg's quotient. Calculating these scores before and after vestibular rehabilitation therapy may aid in evaluating the healing process in clinical practice.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Bayındır Hospital.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - E.S.; Design - E.S.; Supervision - T.O.; Resources - M.E.D., C.C.; Materials - C.C.; Data Collection and/or Processing - B.Y.O., M.K.; Analysis and/or Interpretation - M.E.D., C.C.; Literature Search - M.E.D., B.Y.O., M.K.; Writing Manuscript - E.S.; Critical Review - T.O.

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