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original article

Effectiveness of Virtual Reality Therapy in the Rehabilitation of Isolated Otolith Dysfunction

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ABSTRACT

Background: Previous studies have shown virtual reality (VR) therapy to effectively manage vestibular dysfunction. However, its effectiveness in managing patients specifically diagnosed with Isolated Otolith Dysfunction (IOD) lacks comprehensive documentation. Therefore, the aim of this study was to evaluate the effectiveness of VR therapy in the management of patients with IOD.
Methods: Twenty-one participants were previously diagnosed with IOD by basic audiological assessment along with normal oculomotor tests and a normal video Head Impulse Test results but abnormality in cervical vestibular evoked myogenic potential and/or ocular vestibular evoked myogenic potential were included. Participants underwent a VR therapy program comprising 8-10 sessions, each lasting 15-20 minutes, conducted twice a week. The effectiveness of the therapy was assessed by administering the Dizziness Handicap Inventory (DHI) pre- and post-VR therapy.
Results: The average number of rehabilitation sessions attended by the patients was 8.10. Post-VR therapy, DHI scores decreased by 45% across all aspects. A statistically significant difference was observed between pre- and post-VR DHI scores ($p<0.001$) for the total sample. Additionally, statistically significant differences were found between pre- and post-VR therapy DHI scores ($p<0.001$) when participants were grouped by affected otolith organ (Utricle, Saccule, or both). Similarly, both age groups (20-40 and 41-60 years old) and both genders exhibited improved DHI scores post-VR therapy compared to pre-VR therapy scores ($p<0.001$).
Conclusions: VR therapy demonstrates effectiveness in managing patients with IOD, resulting in a reduction of the negative impact on their quality of life. However, the long-term effect remains unknown and requires further investigation.
Key words: Virtual reality; Dizziness; Saccule and Utricle; Rehabilitation.

INTRODUCTION:

Some patients presenting with symptoms of dizziness exhibit normal outcomes across all semicircular canal assessments, such as the video head impulse test (vHIT) and the caloric test. Despite these unremarkable results, these patients display abnormalities in otolith function assessments, such as cervical vestibular evoked myogenic potential (cVEMP) and/or ocular VEMP (oVEMP). These observations may be indicative of idiopathic otolithic vertigo [1]. Researchers have employed various terminologies to characterize idiopathic otolithic vertigo, including otolith organ-specific vestibular dysfunction, isolated otolith organ dysfunction (IOD), and persistent postural-perceptual dizziness. Another term utilized is episodic lateral tilting or translational sensations [2]. Patients with IOD typically experience non-spinning vertigo, sensations of tilting, rocking, floating, translational movements in the roll pitch planes, or disequilibrium

with drop attacks [3]. According to a study by Chua et al. [4], the prevalence of IOD is notable, with 12% of participants meeting the criteria for definite IOD and 40% considered probable IOD.

Individuals affected with vestibular disorders stand to gain from vestibular rehabilitation, a treatment modality centered on exercise interventions. When an individual exhibits symptoms of motion-induced dizziness and imbalance dysfunction due to vestibular dysfunction, vestibular rehabilitation emerges as aviable intervention [5]. Vestibular rehabilitation therapy represents a specialized exercise regimen aimed at alleviating both primary and secondary manifestations linked with vestibular disorders. Within vestibular rehabilitation therapy, tailored exercises targeting the head, body, and eyes are employed to recondition the brain's capacity to interpret and integrate inputs from the vestibular system, coordinating them with information from the visual and proprioceptive systems. While vestibular rehabilitation has demonstrated efficacy in addressing vestibular dysfunction based on predefined criteria, its success rate may exhibit variability, potentially attributable to the diverse spectrum of vestibular dysfunctions necessitating distinct rehabilitative approaches [6].

Although vestibular rehabilitation has shown efficacy in rehabilitating patients with peripheral vestibular disorders like vestibular neuritis and superior semicircular canal (SSC) dysfunction, its effectiveness in treating patients with otolith disorders remains uncertain [7]. Dougherty et al. [8] reported on the efficacy of rehabilitation programs targeting patients with otolith dysfunction using traditional vestibular rehabilitation methods.

Virtual reality (VR) represents a method for delivering potential reality-based vestibular rehabilitation. VR therapy refers to computer-generated interactive virtual environments that simulate real-world scenarios and are presented to users in three dimensions [6,8]. According to Cano Porras et al. [9], VR-based rehabilitation offers numerous advantages, such as increased motivation and improved motor learning. For example, by offering diverse virtual environments resembling real-life situations, VR therapy can provide real-time intrinsic and extrinsic sensory feedback and promote task variation. Additionally, VR therapy enables control over stimuli and reliability, the ability to divert or enhance the user's attention, and, crucially, therapeutic intervention. VR holds therapeutic promise in vestibular dysfunction rehabilitation by fostering habituation, substitution, and adaptability. It has been investigated as a rehabilitation technique and has demonstrated efficacy in alleviating symptoms associated with various vestibular dysfunctions [10-13]. Therefore, this study aimed to assess the effectiveness of VR therapy in rehabilitating individuals with IOD.

METHODS

In this prospective study, the medical records of 21 participants were driven from the Medical Center and reviewed to identify patients with IOD. Adults aged 18 years or more with a history of chronic dizziness characterized by sensations of tilting, rocking, floating, and/or experiencing drop attacks for more than 3 months and diagnosed with IOD by basic audiological assessment along with normal oculomotor tests and a normal vHIT results but abnormality in cVEMP and/or oVEMP were eligible for inclusion in the study. Abnormality in cVEMP and/or oVEMP was determined by prolonged latency of more than 2 SD and an increase in the asymmetrical ratio of more than 34.4%for cVEMP and 35.3%% for oVEMP [14]. Exclusion criteria encompassed patients using vestibular suppressants for a long time, which were hindering central compensation; patients undergoing traditional vestibular rehabilitation; and patients who had central vestibular affection or semicircular canal dysfunction.

Procedure and Equipment

All patients underwent comprehensive history-taking and otological examination. Additionally, the following audio/vestibular tests were conducted.

Basic audiological evaluation

Pure Tone Audiometry was performed using Interacoustics AD629; this included air conduction (0.25-8 kHz) and bone conduction (0.5- 4 kHz) for both ears. Auditory Thresholds higher than 25 dB were considered abnormal. Additionally, speech reception threshold test was performed using Arabic spondee words [15] and the word discrimination score test using Arabic phonetically balanced words [16]. Moreover, acoustic immittance measurement was done using Interacoustics AT235, including Tympanometry and Acoustic reflex threshold measurements using pure tones [17] (up to 100 dB for ipsilateral and 120 dB for contralateral) at 500, 1000, 2000 and 4000Hz.

Vestibular evaluation

I- Videonystagmography (VNG)

Videonystagmography (VNG) was performed using the Micro medical Visual Eyes 525 by Interacoustics.

In addition, Oculomotor tests (Saccade testing, Smooth Pursuit testing, Optokinetic Nystagmus and Gaze test), Positional tests and Positioning tests(Dix-Hallpike test) were performed [18].

II- vHIT

vHIT was performed using an Otometrics ICS impulse system. Recordings were obtained for each of the six semicircular canals for all participants (horizontal, LARP, and RALP). For the purpose of the test, participants put on a pair of lightweight, tightly fitting goggles on which a small video camera and a half-silvered mirror that reflects the image of the patient's right eye were mounted. Calibration of the eye position signal was carried out with the subject successively fixating on two projected laser dots separated by a known horizontal angle. During the test, participants were instructed to maintain their gaze on an earth-fixed target positioned no less than one meter in front of them. The head movement speed was measured by the sensor in the goggles, and the image of the eye was captured by the high-speed camera (250 Hz) and processed to yield eye velocity. In a full test, 20 impulses were delivered randomly in each direction. At the end of the full test, all the head velocity stimuli and eye velocity responses were displayed on the computer screen, together with a graph of the calculated VOR gain (ratio of eye velocity to head velocity) for every head rotation. The parameters evaluated were the VOR mean gain and the appearance of saccades after head impulses to the right and to the left [19].

III- cVEMP

cVEMP was also conducted using Interacoustic Eclipse. Tone bursts with a tone frequency of 500 Hz and refraction polarity was presented through an inserted headphone with a stimulation rate of 500 Hz with an intensity of 95 dB nHL, rise/fall time, and plateau of 2 msec. The active electrode was placed on the middle part of the Sternocleidomastoid muscle, with the reference electrode was placed over the upper sternum and the ground electrode positioned on the forehead. Two traces from each side were obtained to assess the reproducibility of peaks p13 and n23; thus, cVEMP responses were termed 'present'. Conversely, cVEMP responses were absent when reproducibility of the biphasic p13–n23 waveform was lacking. Thereby, the latencies and amplitude of the peak p13 and peak n23 were measured. The optimal cutoff value of p13 latency was 12.6 msec, and 19.8 msec for n23 (upper 95% confidence limit; CL) [20]. In addition, the upper limit of the ''asymmetry ratio'' (An amplitude ratio between the left-sided and right-sided responses) was 34.4% [14].

oVEMP

Additionally, oVEMP was conducted using Interacoustic Eclipse. Similar stimulus parameters to those used for cVEMP were utilized, the stimulus was delivered to the tested ear (i.e. the ear contralateral to the measured eye). The active electrode was positioned just below the center of the lower eyelid, while the reference electrode was placed on the cheek approximately 1–2 cm below the active electrode. The ground electrode was placed over the forehead. The o-VEMP tracing obtained consists of a biphasic waveform. The first peak has a negative deflection (N) latency of ~10 milliseconds, followed by a positive peak (P) with a mean latency of 16 milliseconds, which are called N1 and P1. On the other hand, oVEMP responses were absent when reproducibility of the biphasic N1and p1 waveform was lacking. The upper 95% CL of N1 latency was 10.7 msec, and 10.7 mesc for P1 latency. Proceeding these limits is considered abnormal. An amplitude ratio between the left-sided and right-sided responses for oVEMP was deemed abnormal if the ''asymmetry ratio'' was more than 35.3%. In such cases, the side with the smallest amplitude was classified as impaired [20].

Dizziness Handicap Inventory (DHI)

All participants underwent baseline assessment using the Arabic Dizziness Handicap Inventory (DHI) prior to enrolling in the rehabilitation program [21]. The DHI consisted of twenty-five questions, categorized into seven questions assessing the physical aspect, nine assessing the emotional aspect, and seven assessing the functional aspect. Participants answered the questions by selecting one of the following responses: "yes", "no" or "sometimes". For each "yes" response, four points were assigned, zero points were assigned for each "no" answer, and two points for each "sometimes" response. Higher score values indicated a greater negative impact on life quality [22]. The questionnaire was applied before and four weeks after completing the rehabilitation sessions to evaluate the effectiveness of the VR therapy program.

Virtual Reality Therapy

The Theme Park Rides game (Oculus Touch) with Hp headset goggles was used as the platform for the rehabilitation program. The system boasted 23 rehabilitative applications (virtual environments), selected based on therapeutic objectives, to be employed during each treatment session. The

duration of the rehabilitation program spanned 8-10 sessions, occurring twice a week, with the precise number of treatments depending on the patient improvement. The duration of a single session ranged from 15 to 20 minutes, adjusted according to the patient's condition. Throughout all stages of the virtual reality therapies, coordination between two audiologists was maintained to assess the patient and operate the VR devices effectively.

The exercises within the rehabilitation program were designed to enhance gaze stability, increase postural stability, improve vertigo, and enhance daily activities through several fully customized stimuli including saccadic, optokinetic nystagmus, smooth pursuit, supermarket effect, and among others. Participants were allocated to VR therapy based on their performance during the initial evaluation. Factors such as patient safety, fall risk, medical history, physical, and balance examination performance, as well as professional judgment, were all taken into consideration during the assignment process.

Ethical Considerations:

Ethical approval was obtained from the Institutional Review Board at Princess Nourah bint Abdulrahman University (IRB Number: 23-0516).

STATISTICAL ANALYSIS:

Statistical analyses were performed using SPSS. Descriptive statistics including frequency and percentage were employed to organize and summarize the age and gender distribution of the patients. The mean ± standard deviation (SD) was utilized to ascertain the average number of rehabilitation sessions attended by the patients. Paired t-tests were conducted to assess the difference between the mean scores for the DHI parameters and to compare participants' scores before and after the VR therapy intervention. A significance level (alpha) of 0.05 was predetermined, indicating that results were considered statistically significant if $P < 0.05$. The null hypothesis was rejected if the P was less than 0.05.

RESULTS:

Among the 21 patients recruited to participate in this study, 12 (57%) were females, and 9 (43%) were males. The majority of participants (52%) fell within the age range of 41to 60 years old, while 48% were between the ages of 20 and 40 years old (Table 1).

As shown in Table 2, the average number of rehabilitation sessions attended by the participants was 8.10, with a slight difference between the two age groups. Participants aged 20-40 years old attended an average of 7.70 rehabilitation sessions, whereas those aged 41-60 years old attended an average of 8.27 sessions.

Audiological and vestibular findings

All participants had bilateral normal hearing thresholds (Table 3). In addition, normal oculomotor test findings were observed in all participants, ruling out central vestibular dysfunction. Furthermore, vHIT findings revealed normal symmetrical gain in the RALP, LARP, and lateral canal for all participants, thereby excluding semicircular canal disease. Regarding VEMP findings, as shown in Tables 4 and 5, prolonged p1-n1 latencies were evident bilaterally in both cVEMP and oVEMP. Moreover, an increase in the asymmetrical ratio was observed, indicative of affected utricles and saccules. Specifically, saccule dysfunction was present in the majority of participants (n=10), while utricle dysfunction was noted in seven participants, and both utricle and saccule dysfunction were observed in four participants (Table 6).

DHI scores pre- and post- VR therapy

A comparison between the DHI scores pre-and-post-VR therapy was conducted using t-test. The results indicated statistically significant (P <0.001) across all aspects of the DHI: emotional, physical, and functional for the total sample (Table 7). Additionally, comparisons of DHI scores pre- and post- VR therapy were performed for various subgroups, including males, females, older age group, younger age group, the group with utricle dysfunction, the group with saccule dysfunction, and the group with dysfunction in both otolith organs. Statistically significant differences (P <0.001) were observed between the DHI scores pre- and post- VR therapy among all subgroups (Tables S1 and S2).

Table 1: Frequency and Percentage Distribution of Participants by Gender and Age.

Demographic profile		Frequency	Percentage
Gender	**Female**	12	57
	Male	9	43
Age	**20-40 years old**	10	48

	41-60 years old	11	52
Age (years)		**Mean age ±SD**	**Range**
		39 ±11	23-60

Table 2: Mean ±SD and Range of the Number of Rehabilitation Sessions Attended by the Participants

	Mean ±SD	**Range**
All Participants (n=21)	8.10 ±0.99	5-10
20-40 years old	7.70 ±1.34	5-8
41-60 years old	8.27 ±1.19	6-10

Table 3: Mean ±SD and Range of Pure Tone Audiometry Thresholds at All Octave Hearing Frequencies in Both Ears

Laterality		**Frequencies (Hz)**					
		250	**500**	**1000**	**2000**	**4000**	**8000**
Right ear	**Mean ±SD** dB HL	14.76 ±4.87	12.38 ±5.15	15.00 ±4.47	14.76 ±5.12	16.43 ±7.27	20.0 0 ±6.32
	Range dB HL	5-20	5-25	10-25	5-25	10-25	10-30
Left ear	**Mean ±SD** dB HL	14.52 ±3.50	10.48 ±4.15	11.19 ±4.98	13.81 ±7.05	18.10 ±6.42	20.7 1 ±7.29
	Range dB HL	10-20	5-2-	5-15	5-20	10-25	10-30

Table 4: Mean ±SD and Range of cVEMP* parameters

cVEMP* parameters			**Mean ±SD**	**Range**
p1-n1 Latencies (msec.)	**p1**	**Right**	15.46 ±1.84	11-19
		Left	14.41 ±2.81	12-19.33
	N1	**Right**	25.22 ±3.97	20.33-37
		Left	24.82 ±4.01	19.33-31.67
p1-n1 Amplitude (uv)	**Right**		60.77 ±53.37	7.33-218.3
	Left		62.48 ±39.22	11.31-124.8
Asymmetrical ratio (%)			49.33 ±7.95	37-64

*cVEMP: cervical vestibular evoked myogenic potential

Table 5: Mean ±SD and Range of oVEMP* parameters

oVEMP parameters			**Mean ±SD**	**Range**
p1-n1 Latencies (msec.)	**p1**	**Right**	11.05 ±2.49	8.1-14.9
		Left	11.37 ±2.38	8.1-14.5
	N1	**Right**	14.21 ±3.83	11-21.1
		Left	15.71 ±2.92	12-19.1
p1-n1 Amplitude (uv)	**Right**		14.68 ±3.85	12-22.9
	Left		15.62 ±4.11	9.9-19.5
Asymmetrical ratio (%)			49.7 ±10.13	37-64

*oVEMP: ocular vestibular evoked myogenic potential

Table 6: Frequency and Percentage Distribution of Participants according to the Affected Otolith Organ

Affected otolith	Frequency	Percentage
Utricle	7	33
Saccule	10	48
Both	4	19

Table 7: Comparison of DHI* Scores Pre- and Post-VR therapy**

DHI	Mean ± SD		Paired t-test	*P-value*
	Pre	Post		
Emotional	16.48 ±1.54	7.43 ± 1.60	-28.97	< 0.001***
Physical	17.05 ±1.75	7.29 ±1.35	-28.93	< 0.001***
Functional	18.43 ±1.89	8.52 ±1.78	-16.16	<0 .001***
Total	51.95 ±2.96	23.24 ±4.02	-36.62	<0 .001***

*DHI: dizziness handicap inventory
**VR therapy: virtual reality therapy
*** Statistically significant

DISCUSSION:

Several studies have been undertaken to establish definitions or diagnostic criteria for IOD [1,2,23]. However, there remains a gap in understanding regarding the efficacy of vestibular rehabilitation for patients diagnosed with IOD. Consequently, the present study sought to explore the effectiveness of VR therapy in the rehabilitation of patients with IOD, utilizing DHI as the primary outcome measure tool.

Previous studies have suggested that lesions affecting the otolith organs may result in more severe symptoms and poorer prognosis compared to lesions affecting other peripheral vestibular organs [24,25]. However, findings by Murray et al. [26] contradicted this notion, as they observed improvements in outcome measures among patients both with and without otolith dysfunction. This suggests that even individuals with some form of otolith dysfunction may experience benefits from vestibular rehabilitation. It is important to note, however, that the participants in Murray et al.'s [26] study either presented with dysfunction in semicircular canals or dysfunction in both semicircular canals and otolith organs. Consequently, no participants with IOD were included in their study cohort. Thus, it remains unclear from this study whether participants specifically diagnosed with IOD would derive similar benefits from vestibular rehabilitation.

In a recent study examining the effectiveness of vestibular rehabilitation across all receptor organs of the vestibular system, promising outcomes were observed following a 12-week vestibular rehabilitation program, encompassing all vestibular dysfunctions, including IOD [27]. Similarly, Yilmaz et al. [28] reported a case of IOD that exhibited improvement after 6 weeks of vestibular rehabilitation. Consistent with these findings, the results of the current study demonstrated favorable outcomes for patients with IOD. Notably, the observed improvement persisted for at least a month post-treatment, indicating that the benefits were not transient. Moreover, the findings suggested that an average of 8 sessions of VR therapy yielded significant improvements in the quality of life of these patients (Table 7). Despite the DHI scores highlighting the significant negative impact of IOD on the quality of life of affected individuals prior to VR therapy, treatment with VR therapy led to a remarkable decrease in these scores, amounting to a 45% reduction. This decrease in DHI scores indicates a substantial improvement in quality of life for patients with IOD. Moreover, statistically significant differences were observed in all aspects of the DHI (physical, emotional, and functional) between pre- and post- VR therapy (Table 7).

The positive impact of VR therapy was evident among all participants, irrespective of the affected otolith organ. This finding holds promise for individuals diagnosed with IOD. Furthermore, gender and age were found to have no discernible effect on the effectiveness of the therapy (Table 8), suggesting that VR therapy is a successful approach suitable for use across various age groups and

genders. This aligns with findings from previous studies where age and gender were reported to have no influence on the benefits derived from vestibular rehabilitation [29,30].

As previously noted, there is a dearth of studies examining the efficacy of VR therapy in managing patients with IOD. However, a study conducted by Stankiewicz et al. [31] reported findings consistent with those observed in the present research. The study aimed to compare the effectiveness of VR therapy with conventional vestibular rehabilitation in treating 20 patients diagnosed with peripheral vestibular dysfunction. In this study, participants were divided into two groups, with each group receiving one of the treatment methods. Patient satisfaction levels were evaluated as the outcome measure using the short form of the Vertigo Symptom Scale and the Visual Analog Scale. The findings of the study revealed that the group undergoing VR therapy exhibited higher levels of satisfaction compared to the other group [31].

The utilization of VR therapy in managing IOD is often underestimated, despite its potential effectiveness. Researchers have explored various techniques to address patients with IOD, but VR therapy has not been extensively studied in this context. For instance, Basta et al. [32] implemented an auditory feedback system as a rehabilitation strategy for IOD. They compared the performance of 13 patients with IOD to a control group following a two-week period of vestibular rehabilitation. The study group had access to the auditory feedback training option available in the Sway-StarTM System, while the control group did not. The findings indicated superior outcomes with the auditory feedback system [32]. Similarly, Ernst et al. [33] reported comparable results. Contrastingly, Zhang et al. [34] opted for a surgical approach, performing vestibule plugging on a 42-year-old male diagnosed with IOD. According to their report, the surgery proved effective in treating the condition. However, it is important to note that while the surgical intervention yielded promising results, non-surgical options are typically recommended as first-line treatments to mitigate potential complications [35].

The findings of the current study are indeed promising, especially regarding the observed patient engagement with VR therapy compared to conventional vestibular rehabilitation. However, it is important to note that the number of participants was small within each subgroup. Therefore, further research with a larger sample size is recommended to provide more robust evidence. Additionally, it is advisable to investigate the long-term effects of VR therapy on patients with IOD.

Conclusions

Virtual Reality Therapy emerges as an effective technique for managing patients diagnosed with IOD. It has demonstrated efficacy in reducing the negative impact on the quality of life of IOD patients, irrespective of the specific affected otolith organ, age, or gender. However, while the short-term benefits are evident, the long-term effects of VR therapy remain unknown and warrant further investigation. Understanding the durability and sustainability of the therapeutic outcomes over time will be crucial in fully assessing the utility of VR therapy as a management strategy for IOD.

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Table S1: Comparison of DHI* Scores Pre- and post-VR therapy** Based on Demographic Data (Age and Sex)

	DHI	Mean ±SD		t-test	*p-value*
		Pre	Post		
Gender					
Female	**Emotional**	16.00 ±1.48	7.33 ±1.61	-19.28	<0 .001***
	Physical	16.50 ±1.62	7.17 ±1.27	-19.36	<0 .001***
	Functional	18.58 ±1.73	8.58 ±1.83	-13.73	<0 .001***
	Total	51.08 ±2.94	23.08 ±4.27	-24.53	<0 .001***
Male	**Emotional**	17.11 ±1.45	7.56 ±1.67	-25.36	<0 .001***
	Physical	17.58 ±1.72	7.44 ±1.51	-25.31	<0 .001***
	Functional	18.22 ±2.17	8.44 ±1.81	-8.87	< .00002***
	Total	53.11 ±2.71	23.44 ±3.91	-29.67	< <0 .001***
Age					
20-40	**Emotional**	16.90 ±1.66	8.60 ±1.07	-19.62	<0 .001***
	Physical	17.70 ±1.77	8.00 ±1.15	-20.52	<0 .001***
	Functional	17.70 ±1.57	9.10 ±1.71	-28.15	<0 .001***
	Total	52.30 ±3.59	25.70 ±3.30	-37.87	<0 .001***
41-60	**Emotional**	16.09 ±1.38	6.36 ±1.21	-27.09	<0 .001***
	Physical	16.45 ±1.57	6.64 ±1.21	-19.59	<0 .001***
	Functional	19.09 ±1.97	8.00 ±1.67	-10.76	<0 .001***
	Total	51.64 ±2.38	21.00 ±3.32	-28.34	<0 .001***

*DHI: dizziness handicap inventory
**VR therapy: virtual reality therapy
*** Statistically significant

Table S2: Comparison of DHI* Scores Pre- and Post-VR therapy** According to the Affected Otolith Organ

Affected otolith	DHI	Mean ±SD		t-test	*p-value*
		Pre	Post		
Utricle	**Emotional**	16.00 ±1.48	7.33 ±1.61	-19.28	<0 .001***
	Physical	16.50 ±1.62	7.17 ±1.27	-19.36	<0 .001***
	Functional	18.58 ±1.73	8.58 ±1.83	-13.73	<0 .001***
	Total	51.08 ±2.94	23.08 ±4.27	-24.53	<0 .001***
Saccule	**Emotional**	17.11 ±1.45	7.56 ±1.67	-25.36	<0 .001***
	Physical	17.58 ±1.72	7.44 ±1.51	-25.31	<0 .001***
	Functional	18.22 ±2.17	8.44 ±1.81	-8.87	< 0.00002***
	Total	53.11 ±2.71	23.44 ±3.91	-29.67	<0 .001***
Both	**Emotional**	16.25 ±2.21	7.25 ±1.51	6.73	0.0005***
	Physical	17.5 ±2.38	8 ±1.82	6.34	0.0007***
	Functional	20.25 ±2.06	9.75 ±2.21	6.95	0.0004***
	Total	54 ±3.55	25 ±5.41	8.96	0.0001***

*DHI: dizziness handicap inventory
**VR therapy: virtual reality therapy
*** Statistically significant