MEDICAL SCIENCE MONITOR

CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2020; 26: e930182
DOI: 10.12659/MSM.930182

Received: 2020.12.01
Accepted: 2020.12.30
Available online: 2020.12.31
Published: 2020.12.31

Virtual Reality Vestibular Rehabilitation in 20 Patients with Vertigo Due to Peripheral Vestibular Dysfunction

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEF 1 Tomasz Stankiewicz
CDEF 2 Mariusz Gujski
ACDE 1,3 Artur Niedzielski
BCDE 3 Lechosław P. Chmielik

1 Independent Otoneurology Lab, Medical University of Lublin, Lublin, Poland
2 Department of Prevention of Environmental Hazards and Allergology, Medical University of Warsaw, Warsaw, Poland
3 Paediatric Otolaryngology Clinic, Medical Centre for Postgraduate Education, Warsaw, Poland

Corresponding Author: Mariusz Gujski, e-mail: mariusz.gujski@wum.edu.pl
Source of support: Departmental sources

Background: Vestibular compensation is disrupted in patients with chronic vestibular syndrome. Vestibular rehabilitation is an exercise therapy that optimizes the process of vestibular compensation. This study aimed to evaluate virtual reality (VR) vestibular rehabilitation in 20 patients with vertigo due to peripheral vestibular dysfunction at a single center.

Material/Methods: Our study aim was to initially assess the impact of using virtual reality technology in vestibular rehabilitation. The subjects were 20 patients with unilateral vestibular hypofunction (UVH), as confirmed by videonystagmography. These were divided into 2 groups: Group 1 underwent vestibular rehabilitation using virtual reality and Group 2 was treated by conventional therapy. A VSS-SF questionnaire and the VAS scale were used to assess the effects and levels of patient satisfaction with therapy.

Results: Both groups demonstrated significantly ($P<0.001$) lower values on the VSS-SF scales and VAS scales when assessed after treatment as compared to before treatment. Those undergoing conventional therapy reported significantly more severe symptoms on the VAS scale than did Group 1 at their second and third therapy visits. Indeed, Group 1 patients that underwent rehabilitation with the virtual reality component awarded significantly higher ($P=0.015$) levels of subjective satisfaction when compared to Group 2.

Conclusions: We found that virtual reality vestibular rehabilitation in patients with vertigo due to peripheral vestibular dysfunction was as effective as conventional rehabilitation, with significantly increased levels of patient satisfaction.

Keywords: Vertigo • Vestibular Diseases • Virtual Reality Exposure Therapy

Abbreviations: **VR** – virtual reality; **UVH** – unilateral vestibular hypofunction; **VSS-SF** – Vertigo Symptom Scale – Short Form; **VAS** – Visual Analog Scale; **BPPV** – benign paroxysmal positional vertigo; **CP** – canal paresis; **ANOVA** – one-way analysis of variance; **LSD** – least significant difference; **VSS-SF (P)** – outcome scores from the VSS-SF questionnaire at the initial visit; **VAS (P)** – an assessment of vertigo intensity using the VAS scale at the initial visit; **VAS (W1)** – therapy visit No. 1; an assessment of vertigo intensity using the VAS scale; **VAS (W2)** – therapy visit No. 2; an assessment of vertigo intensity using the VAS scale; **VAS (W3)** – therapy visit No. 3; an assessment of vertigo intensity using the VAS scale; **VAS (W4)** – therapy visit No. 4; an assessment of vertigo intensity using the VAS scale; **VAS (W5)** – therapy visit No. 5; an assessment of vertigo intensity using the VAS scale; **VAS (K)** – an assessment of vertigo intensity using the VAS scale at the final visit; **VSS-SF (K)** – outcome scores from the VSS-SF questionnaire at the final visit; **VAS (SAT)** – grades of satisfaction after therapy awarded by the patient at their final visit

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/930182

3047 6 4 42

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Background

The symptoms of a vestibular disorder include vertigo, dizziness, vestibulo-visual, and postural symptoms [1].

Vertigo and dizziness generally occur in about 20-30% of adults and in 8-18% of children. Its prevalence significantly increases after 65 years of age and is an adverse symptom very commonly reported to GPs at health centers (termed primary health care in Western countries) [2-4]. The sense of equilibration can be disrupted by many and diverse disorders according to etiology, disease course, severity, prognosis, and treatment [5]. Irrespective of cause, this poses many diagnostic challenges for medical practitioners, including devising plans for effective treatment, as such symptoms inevitably lead to their patients' daily lives becoming very onerous and awkward [6]. A sense of balance is crucial to how humans function, most importantly in performing everyday activities. This delivers information on gravity, angular and linear acceleration acting on the human body, as well as the body's orientation in its surrounding space. Spatially maintaining the desired posture and balance depends on the appropriate interactions of the vestibular system, the cerebellum, the organs of vision, and proprioceptors located within the locomotory system. Such sensory impulses are also integrated and enriched by information received from the hearing/auditory and olfactory organs by means of numerous interconnections within the central nervous system. The vestibular organ constitutes a sensory system directly impacting the equilibration system that, both phylogenetically and ontogenetically, belongs to one of the oldest structures of the nervous system [7-9].

Diseases of the vestibular organ are treated by many different vestibular rehabilitation therapies, reflecting its multifactorial etiology, including patients with vertigo. Such therapies are mainly focused on pharmacological treatment (symptomatic and causal), surgical treatment (for pathologies of the inner and/or middle ear structures, Meniere's disease, VIII nerve tumors and in cervical spine diseases), and locomotory rehabilitation [9-11]. The latter's aim is to accelerate the process of centrally acting compensation by taking advantage of physiological mechanisms operating at the central nervous system level. It is currently believed that such means of acceleration can be achieved through exposure to sensory conflicts, which gradually fade out the response to stimuli during habituation [12]. A special form of locomotory rehabilitation is repositioning maneuvers used for treating benign paroxysmal positional vertigo (BPPV), based on the concept of mechanical disturbances to the semicircular canal complex [13]. These include Brandt and Daroff's positional exercises, the Semont release maneuver, and the Epley reposition maneuver [14-16]. Habituation exercises are most often used in rehabilitating any cases of peripheral damage to the vestibular system. Vestibular rehabilitation is a safe and effective method for vestibular rehabilitation and in treating unilateral vestibular hypofunction [17,18]. Exercises that provoke multisensory conflicts by using virtual reality technology have recently been introduced to improve the effectiveness of this therapy [11]. Virtual reality (VR) can be defined as using computer technology to create a simulated image/environment of objects, space, and events. It can represent both a real and fictional world [19]. This virtual world so generated includes not only visual content, but also sound, smell, and touch and allows interaction with the recipient. This technology has been increasingly used for both education and leisure/entertainment. It has been used in civil and military aviation simulators, construction machine simulators, and in creating virtual museums and shops. This technology is also increasingly being used in medicine, not only for interactive training in simulation centers, but also as an element of therapy. Virtual reality is used as an aid in physical rehabilitation after stroke, in Alzheimer disease, in Parkinson disease, for analgesic treatment of burns, in psychological therapies, and in treating post-traumatic stress disorder [20-25]. The benefits of using VR have also been increasingly reported in the literature for treating children with autism spectrum disorders [26]. It is thus expected that VR technology will increasingly have further applications in medicine due to the dynamic developments in this field. Vestibular compensation is disrupted in patients with a chronic vestibular syndrome. Vestibular rehabilitation is an exercise therapy that optimizes the process of vestibular compensation. Therefore, this study aimed to evaluate virtual reality vestibular rehabilitation in 20 patients with vertigo due to peripheral vestibular dysfunction at a single center.

Material and Methods

Patients

All procedures performed in this study were in accordance with the standards of the local Ethics Committee and informed consent was obtained from all participants prior to study initiation. Twenty patients diagnosed with vertigo were selected for the study, consisting of 9 women and 11 men aged 29 to 66 years. All had undergone laryngological and otoneurological examinations, including the Dix-Hallpike diagnostic maneuver, to exclude patients with mild positional vertigo. Both videonystagmographic examination and basic audiological diagnostics (tonal audiometry, tympanometry) were performed. Patients became eligible when exhibiting vertigo with chronic unilateral peripheral damage to the vestibular system according to International Classification of Vestibular Disorders [5]. UVH was confirmed by videonystagmography, with CP (canal paresis) >25% and no vestibular compensation. Exclusion criteria were patients whose health condition precluded them

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

from taking part in the therapy, the coexistence of neurological diseases, or a positive outcome in the Dix-Hallpike diagnostic maneuver. Patients meeting the defined criteria were randomly divided into 2 groups.

Group 1 consisted of 10 patients, (4 women and 6 men aged 36 to 66 years; mean age 49.7), who had been treated with virtual reality. These patients underwent a series of 5 treatment sessions for 5 consecutive days, during which a set of conventional Cawthorne-Cooksey exercises were performed, but enriched with exercises using virtual reality. These VR exercises were conducted in 2 sessions of 5 minutes with 5-minute intervals.

Group 2 were also composed of 10 patients, (5 women and 5 men), aged 29 to 63 years (mean age 48.2), who had undergone standard therapy consisting of a series of 5 treatment sessions for 5 consecutive days, with patients performing a set of conventional Cawthorne-Cooksey exercises [27]. Both groups of patients participated in the exercises under constant medical supervision.

Virtual reality was experienced by using goggles based on the Google Cardboard platform. The VR goggles used the 'VR Roller Coaster' application during exercises that simulated a roller-coaster ride; an entertainment application comprised of steep hills and valleys over which one travels in an open-top train carriage with other passengers. In reality, these railway passengers would experience very strong sensations caused by the rapidly successive and sudden changes in gravity and speed. The VR goggles worn by the patients throughout the exercise prevent seeing anything of the real environment (**Figure 1**).

Figure 1. A patient wearing virtual reality goggles during exercises.

Measurement Tools

Treatment outcomes were assessed by the Vertigo Symptom Scale - Short Form (VSS-SF) scale and the Visual Analog Scale (VAS) [28,29]. The VSS-SF questionnaire was completed by the patient before the study and 4 weeks after the end of the study, together with subjectively assessing the intensities of vertigo/dizziness using the VAS scale before and after the study, as well as at each therapeutic visit. A score of 0 indicated no symptoms and 10 indicated a maximum intensity of symptoms. Patients were also asked to grade their levels of satisfaction with their treatment by again using the VAS scale up to when their treatment had been completed; a score of 0 indicated very dissatisfied, whereas 10 was very satisfied. The VSS-SF scale is a shortened version of the VSS scale which was based on a scale developed by Yardley in 1992, that refers to both physical sensations and the emotional state of the patient [29]. The results were assessed by the summarized version of the VSS-SF scale. After 5 such therapy visits, all patients were recommended to continue their daily rehabilitation using the Cawthorne-Cooksey exercises in their homes [27]. The effects of treatment were assessed after 4 weeks from the patient's last therapy visit using the VSS-SF questionnaire, while patients' conditions were evaluated according to the VAS scale, together with evaluating patient satisfaction using the VAS scale.

Statistical Analysis

The IBM SPSS Statistics 21 package was used to provide answers to the basic questions posed by this study. Summary statistics were thus performed along with a series of *t* tests for independent and dependent samples, as well as one-way analysis of variance (ANOVA) for dependent samples. *P* values of <0.05 were taken as being statistically significant, while $0.05< P<0.1$ were considered as showing a statistical trend. A Shapiro-Wilks test was initially performed to confirm that the data were normally distributed, the only exception being the VAS scale results from the third therapy visit and satisfaction outcomes. Nevertheless, the skewness values did not exceed the conventional absolute value of 0.8, thereby indicating that the variable's distribution was not grossly asymmetric to a normal (Gaussian) distribution. For these reasons, parametric tests were used in this study.

Results

All 20 patients completed therapy. The measured results of VSS-SF and VAS tests are summarized in the **Table 1** for Group 1 and **Table 2** for Group 2. **Table 3** shows the summary statistics and tests for normality.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 1. Summary results – Group 1 (VR extended therapy).

Group 1			Initial visit		Therapy visits					Last visit		
Lp	Age	Sex	VSS-SF (P)	VAS (P)	VAS (W1)	VAS (W2)	VAS (W3)	VAS (W4)	VAS (W5)	VAS (K)	VSS-SF (K)	VAS (SAT)
1	52	M	12	6	6	5	5	5	3	3	3	9
2	58	M	22	7	6	4	3	4	4	4	15	8
3	65	K	17	4	3	3	3	2	2	3	5	9
4	42	M	11	5	4	2	2	4	2	2	9	5
5	36	K	18	4	5	5	5	4	4	3	12	8
6	51	K	13	3	2	2	1	0	0	0	4	10
7	66	M	8	4	3	1	2	1	1	1	4	9
8	48	M	10	4	4	4	2	2	2	1	8	9
9	40	M	12	6	6	3	1	0	0	0	3	10
10	39	K	14	5	4	3	3	2	2	1	4	10

VSS-SF (P) – outcome scores from the VSS-SF questionnaire at the initial visit; VAS (P) – an assessment of vertigo intensity using the VAS scale at the initial visit; VAS (W1) – therapy visit No. 1; an assessment of vertigo intensity using the VAS scale; VAS (W2) – therapy visit No. 2; an assessment of vertigo intensity using the VAS scale; VAS (W3) – therapy visit No. 3; an assessment of vertigo intensity using the VAS scale; VAS (W4) – therapy visit No. 4; an assessment of vertigo intensity using the VAS scale; VAS (W5) – therapy visit No. 5; an assessment of vertigo intensity using the VAS scale; VAS (K) – an assessment of vertigo intensity using the VAS scale at the final visit; VSS-SF (K) – outcome scores from the VSS-SF questionnaire at the final visit; VAS (SAT) – grades of satisfaction after therapy awarded by the patient at their final visit.

Table 2. Summary results – Group 2 (conventional therapy).

Group 2			Initial visit		Therapy visits					Last visit		
Lp	Age	Sex	VSS-SF (P)	VAS (P)	VAS (W1)	VAS (W2)	VAS (W3)	VAS (W4)	VAS (W5)	VAS (K)	VSS-SF (K)	VAS (SAT)
1	60	M	15	5	7	7	5	5	4	5	13	5
2	32	K	9	3	3	3	2	1	1	0	6	3
3	55	M	16	8	8	5	5	5	5	4	10	5
4	56	M	16	5	4	4	4	3	1	1	9	10
5	47	K	25	7	6	5	5	5	6	5	17	4
6	63	M	19	4	4	4	4	4	4	4	15	6
7	29	K	8	6	5	3	2	2	2	1	5	6
8	41	K	13	2	3	4	3	3	3	2	7	9
9	40	K	17	3	3	3	3	1	2	1	6	8
10	59	M	13	9	7	4	5	3	4	3	8	8

VSS-SF (P) – outcome scores from the VSS-SF questionnaire at the initial visit; VAS (P) – an assessment of vertigo intensity using the VAS scale at the initial visit; VAS (W1) – therapy visit No. 1; an assessment of vertigo intensity using the VAS scale; VAS (W2) – therapy visit No. 2; an assessment of vertigo intensity using the VAS scale; VAS (W3) – therapy visit No. 3; an assessment of vertigo intensity using the VAS scale; VAS (W4) – therapy visit No. 4; an assessment of vertigo intensity using the VAS scale; VAS (W5) – therapy visit No. 5; an assessment of vertigo intensity using the VAS scale; VAS (K) – an assessment of vertigo intensity using the VAS scale at the final visit; VSS-SF (K) – outcome scores from the VSS-SF questionnaire at the final visit; VAS (SAT) – grades of satisfaction after therapy awarded by the patient at their final visit.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

Table 3. Summary statistics for the measured variables using the Shapiro-Wilk test.

	M	Mdn	SD	Sk.	Kurt.	Min.	Max	S-W	Significance
Initial VSS-SF	14.40	13.50	4.49	0.63	0.28	8.00	25.00	0.96	0.550
Initial VAS	5.00	5.00	1.81	0.54	-0.11	2.00	9.00	0.96	0.469
Therapy 1 VAS	4.65	4.00	1.66	0.39	-0.82	2.00	8.00	0.93	0.168
Therapy 2 VAS	3.70	4.00	1.34	0.32	0.95	1.00	7.00	0.94	0.258
Therapy 3 VAS	3.25	3.00	1.41	0.01	-1.34	1.00	5.00	0.88	0.016
Therapy 4 VAS	2.80	3.00	1.67	-0.17	-1.16	0.00	5.00	0.92	0.095
Therapy 5 VAS	2.60	2.00	1.64	0.24	-0.53	0.00	6.00	0.95	0.304
Therapeutic mean VAS	3.40	3.00	1.37	0.20	-0.97	1.00	5.60	0.95	0.319
Final VAS	2.20	2.00	1.64	0.28	-1.16	0.00	5.00	0.91	0.064
Final VSS-SF	8.15	7.50	4.30	0.70	-0.60	3.00	17.00	0.92	0.080
Satisfaction assessment of therapy	7.55	8.00	2.21	-0.66	-0.85	3.00	10.00	0.88	0.020

M – mean; Mdn – median; SD – standard deviation; Sk. – skewness; Kurt. – kurtosis; S-W – Shapiro-Wilk test outcome. Table includes statistics for: 1) VAS scale results at the initial, final and therapy visits; 2) Results from VSS-SF questionnaire at the initial and final visit; 3) Result of satisfaction after therapy at final visit.

Table 4. Differences in outcomes between the VAS and VSS-SF scales depending on the type of therapy.

	Group 1 VR extended therapy (n=10)		Group 2 Conventional therapy (n=10)		t	p	95% CI		Cohen d
	M	SD	M	SD			LL	UL	
Initial VSS-SF	13.70	4.19	15.10	4.89	-0.688	0.500	-5.677	2.877	0.308
Initial VAS	4.80	1.23	5.20	2.30	-0.485	0.633	-2.132	1.332	0.217
Therapy 1 VAS	4.30	1.42	5.00	1.89	-0.938	0.361	-2.267	0.867	0.420
Therapy 2 VAS	3.20	1.32	4.20	1.23	-1.756	0.096	-2.197	0.197	0.785
Therapy 3 VAS	2.70	1.42	3.80	1.23	-1.853	0.080	-2.347	0.147	0.829
Therapy 4 VAS	2.40	1.78	3.20	1.55	-1.073	0.297	-2.366	0.766	0.480
Therapy 5 VAS	2.00	1.41	3.20	1.69	-1.724	0.102	-2.662	0.262	0.771
Therapeutic mean VAS	2.92	1.27	3.88	1.36	-1.636	0.119	-2.193	0.273	0.732
Final VAS	1.80	1.40	2.60	1.84	-1.095	0.288	-2.334	0.734	0.490
Final VSS-SF	6.70	4.16	9.60	4.12	-1.566	0.135	-6.790	0.990	0.700
Satisfaction assessment of therapy	8.70	1.49	6.40	2.27	2.676	0.015	0.494	4.106	1.197

Table includes statistics for: 1) VAS scale results at the initial, final and therapy visits; 2) Results from VSS-SF questionnaire at the initial and final visit; 3) Result of satisfaction after therapy at final visit.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

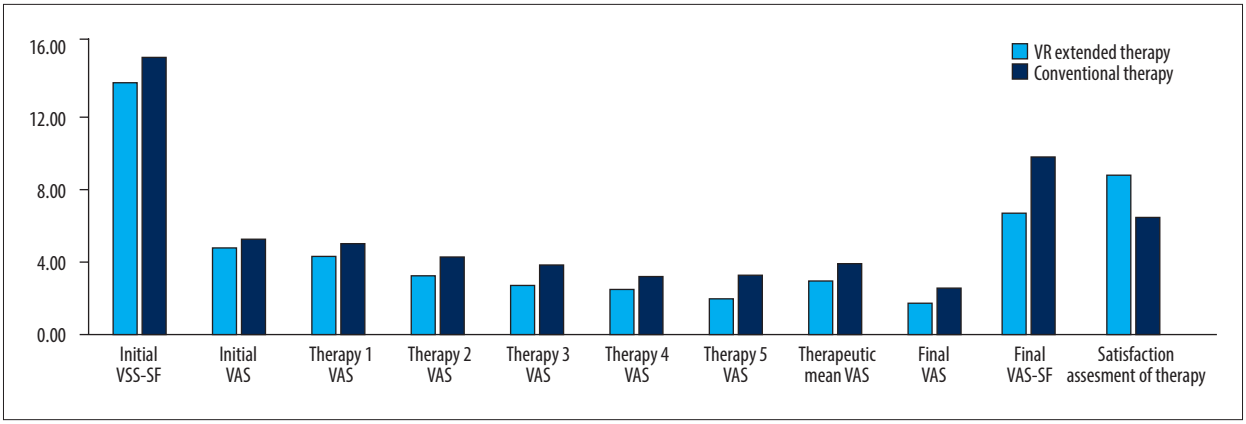

Figure 2. Differences in outcomes between VAS and VSS-SF scales depending on the type of therapy.

Table 5. Differences in VSS-SF scale results depending on the time interval in Group 1 (VR extended therapy) and Group 2 (conventional therapy).

		M	SD	t	p	95% CI		Cohen d
						LL	UL	
Group 1 VR extended tharapy	Initial VSS-SF	13.70	4.19	6.450	<0.001	4.545	9.455	2.040
	Final VSS-SF	6.70	4.17					
Group 2 Conventional therapy	Initial VSS-SF	15.10	4.89	6.398	<0.001	3.556	7.445	2.023
	Final VSS-SF	9.60	4.12					

Differences in outcomes between the VAS and VSS-SF scales depending on the type of therapy are shown in **Table 4**. The independent-samples *t* test was used to determine whether the treatment therapy made a significant difference to the test subjects according to VAS and VSS-SF scales. It was indeed found that assessments of subjects' satisfaction with the therapy differed significantly (*P*=0.015): VR extended therapy M=8.70±1.49, conventional therapy M=6.40±2.27, while a statistically significant trend was found in the VAS during the second (VR extended therapy M=3.20±1.32; conventional therapy M= 4.20±1.23) and third therapy visits (VR extended therapy M=2.70±1.42; conventional therapy M=3.80±1.23). Those undergoing conventional therapy demonstrated higher VAS scale results at the second (*P*=0.096) and third (*P*=0.080) therapy visits, whereas the test group (ie, those having the additional VR therapy) gave higher subjective scale marks when assessing satisfaction with their therapy. This means that subjects who had undergone only conventional therapy made stronger complaints during their second and third therapeutic visits along with giving lower levels of satisfaction with the therapy than those who had their therapy augmented with virtual reality exercises. The magnitude of the difference between 2 means (Cohen's d) indicates that in the aforementioned cases such differences are strong (d=0.785; d=0,829) and very strong (d=1.197), respectively, in terms of satisfaction with therapy. There were, however, no significant differences in statistical trends between any of the other measurements according to the VAS and VSS-SF scales; subjects achieved similar scores irrespective of the therapy, as shown in the graph in **Figure 2**.

Differences in VSS-SF scale results depending on the time interval are shown in **Table 5**. The *t* test was performed on the dependent samples to check whether there were any statistically significant differences between the VSS-SF scale measurements in the compared groups. Results in Group 1 at initial VSS-SF assessment were M=13.70±4.19 and final VSS-SF assessment M=6.70±4.17. Results in Group 2 initial VSS-SF assessment were M=15.10±4.89 and final VSS-SF assessment M=9.60±4.12. These indeed demonstrated statistically significant differences between the VSS-SF measurements in Groups 1 and 2. In both cases, the VSS-SF scale results were significantly (*P*<0.001) lower in the final measurement when compared to the initial measurement. Cohen's d value (d=2.040; d=2.023) indicated that such differences were very strong; this is shown graphically in **Figure 3**.

Differences in VAS scale results between the time intervals are collected in **Table 6**. A one-way analysis of variance (ANOVA) was next performed for dependent samples to investigated whether there were any statistically significant differences between the initial results of measurement, averaged results from therapeutic visits, and the final VAS scale result in Group

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

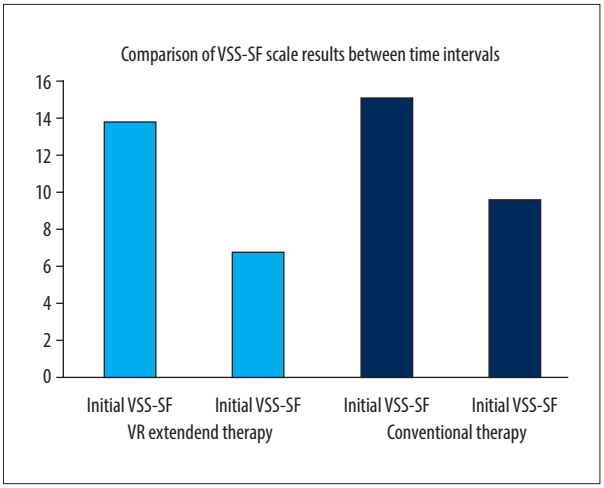

Figure 3. Comparison of VSS-SF scale results between time intervals.

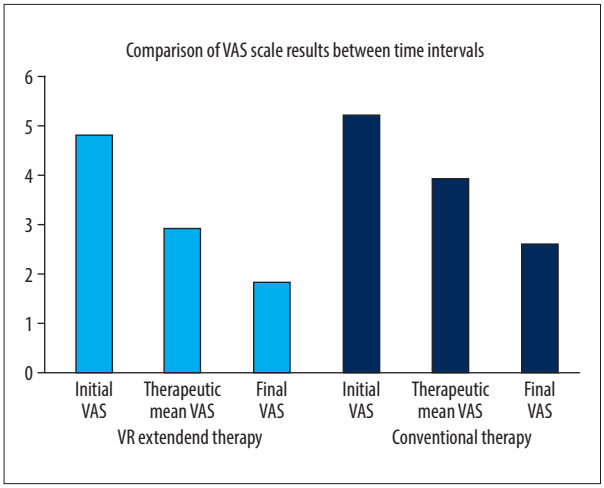

Figure 4. Comparison of VAS scale results between the time intervals.

Table 6. Differences in VAS scale results between the time intervals for Group 1 (VR therapy applied group) and Group 2 (conventional therapy group).

		M	SD	F	p	η^2
Group1 VR extended tharapy	Initial VAS	4.80_a	1.23	33.475	<0.001	0.788
	Therapeutic VAS	2.92_b	1.27			
	Final VAS	1.80_c	1.80			
Group2 Conventional therapy	Initial VAS	5.20_a	2.30	12.328	0.005	0.578
	Therapeutic VAS	3.88_b	1.36			
	Final VAS	2.60_c	1.84			

Means indivisible by the letter index differed significantly from each other at p<0.05.

1 (ie, where therapy had been extended with virtual reality exercises) and in Group 2 (ie, conventional therapy). Significantly different outcomes were again found in both groups (Group 1, *P*<0.001; Group 2, *P*=0.005). Results in Group 1: Group 1 Initial VAS M=4.80±1.23; Therapeutic VAS M=2.92±1.27; Final VAS M=1.80±1.80. Results in Group 2: Group 2 Initial VAS M=5.20±2.30; Therapeutic VAS M=3.88±1.36; Final VAS M=2.60±1.84. Post hoc LSD comparative tests were performed to precisely determine which measurements were different from each other. This showed statistically significant differences existing between all of the analyzed variables. In both groups, the highest result on the VAS scale was recorded at the initial measurement, but were significantly weaker during the therapeutic visits, while the weakest was at the final visit. The Cohen d difference measure in the magnitude of effect indicates that there are large (η^2=0.788) and moderately large (η^2=0.578) differences in Group 1 and Group 2, respectively. This is shown graphically in **Figure 4**.

Discussion

The study aim was to initially assess how effective the use of VR was in vestibular rehabilitation. Patients' compensatory mechanisms were found to be enhanced by introducing a sensory conflict through using new-generation VR goggles, and this new therapy is well tolerated. It is noteworthy to report that our subjects never complained of any adverse effects of the applied therapy, which could have included motion sickness symptoms, which have been observed in other studies that used VR [30]. The effectiveness of such therapy was evaluated by analyzing the intensity of vertigo along with reported satisfaction with the therapy by means of the VSS-SF questionnaire and VAS scale. We demonstrated significantly higher levels of patient satisfaction in those undergoing the extended VR therapy when compared to conventional therapy, thereby highlighting the advantages of therapy reinforced by VR. Even though the end outcomes were similar in both groups, those patients that additionally underwent VR therapy reported much higher levels of satisfaction regarding the severity of their vertigo when measured by the VAS scale

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

using the VSS-SF questionnaire. A higher statistical trend was also observed in such patients for reporting satisfaction at the second and third therapy visits, thereby supporting the advantages of additional VR therapy. This means that any beneficial therapeutic effects are experienced earlier in patients undergoing therapy extended by VR when compared to those treated conventionally. A satisfactory outcome was observed in all treated patients as measured by the VAS scale. The advantages of using additional VR therapy were again statistically demonstrated when comparing the averaged visit results with the final outcome measurements.

According to The Cochrane Review, vestibular rehabilitation is a safe and effective management for unilateral peripheral vestibular dysfunction [17]. A study by Vugt et al showed benefits of new technologies involved in vestibular rehabilitation. Use of internet-based vestibular rehabilitation protocols is a safe, effective, and easy accessible form of therapy for adults aged 50 and older with a chronic vestibular syndrome [10,31]. Many studies have shown the great potential and efficacy of VR when treating patients suffering from vertigo [30,32-35]. These have incorporated VR with motion sensors that permit interaction with a suitable computer device based on recognizing human gestures and voice commands. Any interaction is triggered by the user's body language, generating visual feedback in the form of mapped-out movements displayed on the computer screen or according to a defined program of graphically displayed responses. These devices do not, however, generate a spherical stereoscopic image. The image seen on the monitor or projection screen is that displayed by 2D technology (ie, 2 dimensional).

Using the new generation of VR goggles, however, enables images to be displayed in both 2D and 3D (ie, stereoscopically). The combination of coupling goggles with the gyroscopic and accelerometer devices fully permits any displaced head movements to be fully observed by created VR inputs within a 360-degree range. This significantly enhances the experience of VR, provides stronger stimuli, and evokes real-life sensations [34,36]. A study by Virre and Sitarz showed that VR has a beneficial effect on the efficiency of the vestibulo-ocular reflex and in reducing vertigo [37]. Sparrer et al found that VR benefits patients with vertigo, as confirmed by posturographic tests and survey outcomes [35].

The significance of VR has been stressed by Pavlou et al, where it was found to be very useful in patients with unilateral peripheral damage to the vestibular organ. They demonstrated that patients treated with VR or by conventional therapy improved by 59.2% and 28.8%, respectively, compared to 1.6% of untreated patients [38]. A study by Duque et al showed that elderly patients treated with VR also improved their sense of balance [39]. However, a study by Meldrum et al found comparable efficacies between VR therapy and conventional vestibular rehabilitation [11]. A study by Jozefowicz-Korczynska et al on the effect of VR on vertigo patients undergoing rehabilitation suggested that this is an effective and well tolerated method of therapy, despite not significantly differing in outcome to posturographic platform exercises [32]. Using a combination of VR, motion sensors, and a posturographic platform in rehabilitation (ie, a hybrid therapy) was found to be effective by Rosiak et al in reducing the subjectively assessed symptoms in patients with peripheral vestibular dysfunction [33]. A study by Micarelli et al assessing vestibular rehabilitation using VR goggles in home-based patients found that this method is safe and increases the patient's quality of life [40]. Using goggles, together with tracking eyeball movement, was found by Park et al to improve vestibular rehabilitation [41]. There are also reports presenting a negative impact of VR on balance in healthy adults. A study by Lee et al found longer use of a head-mounted VR display affected static balance, oculomotor function, and dizziness [42].

The majority of head-mounted VR devices used for treating vertigo are either old types or video games without providing any stereoscopic images. Such devices also fail to correlate head movements with those in a virtual environment. A new generation of devices, such as the ones used in this study, are more immersive and create a potentially greater sensory conflict. It should be taken into account that our results come from a single-center study on a small group of patients. This may have had an impact on the overall assessed effectiveness of the therapy and detection of possible adverse effects.

Conclusions

The findings from this study showed that virtual reality vestibular rehabilitation in patients with vertigo due to peripheral vestibular dysfunction was as effective as conventional rehabilitation, with significantly increased levels of patient satisfaction. It can thus be concluded that such new-generation VR devices will likely be used more and more in the rehabilitation of patients with balance disorders. Our study outcomes encourage careful monitoring of the development of VR technology and may provide a basis for further and larger studiers, with particular emphasis on therapeutic protocols and the intensity and duration of therapy.

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]

References:

1. Bisdorff A, Von Brevern M, Lempert T, Newman-Toker DE. Classification of vestibular symptoms: Towards an international classification of vestibular disorders. J Vestib Res. 2009;19:1-13
2. Colledge NR, Barr-Hamilton RM, Lewis SJ, et al. Evaluation of investigations to diagnose the cause of dizziness in elderly people: A community based controlled study. BMJ. 1996;313:788-92
3. Mielnik-Niedzielska G. [Specyfika zawrotów głowy u dzieci.] Otorynolaryngologia. 2015;4:191-95 [in Polish]
4. Neuhauser HK. Epidemiology of vertigo. Curr Opin Neurol. 2007;20:40-46
5. Bisdorff AR, Staab JP, Newman-Toker DE. Overview of the International Classification of Vestibular Disorders. Neurol Clin. 2015;33:541-50,vii
6. Polensek SH, Sterk CE, Tusa RJ. Screening for vestibular disorders: A study of clinicians' compliance with recommended practices. Med Sci Monit. 2008;14:CR238-42
7. Eggers SDZ, Zee DS. Vertigo and imbalance: Clinical neurophysiology of the vestibular system. 2010
8. Janczewski G. [Zawroty głowy (vertigo): Kompendium lekarza praktyka.] Warszawa: Solvay Pharma; 1995 [In Polish]
9. Narożny W, Skarżyński H, Medical Education. [Zarys otoneurologii. T. 1.] Warszawa: Medical Education Grupa Wydawnicza; 2018 [in Polish]
10. van Vugt VA, van der Wouden JC, Essery R, et al. Internet based vestibular rehabilitation with and without physiotherapy support for adults aged 50 and older with a chronic vestibular syndrome in general practice: Three armed randomised controlled trial. BMJ. 2019;367: l5922
11. Meldrum D, Herdman S, Moloney R, et al. Effectiveness of conventional versus virtual reality based vestibular rehabilitation in the treatment of dizziness, gait and balance impairment in adults with unilateral peripheral vestibular loss: A randomised controlled trial. BMC Ear Nose Throat Disord. 2012;12:3
12. Rine RM, Schubert MC, Balkany TJ. Visual-vestibular habituation and balance training for motion sickness. Phys Ther. 1999;79:949-57
13. Korres SG, Balatsouras DG, Papouliakos S, Ferekidis E. Benign paroxysmal positional vertigo and its management. Med Sci Monit. 2007;13:CR275-82
14. Parnes LS, Agrawal SK, Atlas J. Diagnosis and management of benign paroxysmal positional vertigo (BPPV). CMAJ. 2003;169:681-93
15. Brandt T, Steddin S, Daroff RB. Therapy for benign paroxysmal positioning vertigo, revisited. Neurology. 1994;44:796-800
16. Semont A, Freyss G, Vitte E. Curing the BPPV with a liberatory maneuver. Adv Otorhinolaryngol. 1988;42:290-93
17. McDonnell MN, Hillier SL. Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. Cochrane Database Syst Rev. 2015;1:CD005397
18. Hall CD, Herdman SJ, Whitney SL, et al. Vestibular rehabilitation for peripheral vestibular hypofunction: An evidence-based clinical practice guideline: From the American Physical Therapy Association Neurology Section. J Neurol Phys Ther. 2016;40:124-55
19. Cipresso P, Giglioli IAC, Raya MA, Riva G. The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. Front Psychol. 2018;9:02086
20. Maples-Keller JL, Bunnell BE, Kim S-J, Rothbaum BO. The use of virtual reality technology in the treatment of anxiety and other psychiatric disorders. Harv Rev Psychiatry. 2017;25:103-13
21. Botella C, Baños RM, Villa H, et al. Virtual reality in the treatment of claustrophobic fear: A controlled, multiple-baseline design. Behavior Therapy. 2000;31:583-95
22. Cano Porras D, Siemonsma P, Inzelberg R, et al. Advantages of virtual reality in the rehabilitation of balance and gait: Systematic review. Neurology. 2018;90:1017-25
23. Li A, Montaño Z, Chen VJ, Gold JI. Virtual reality and pain management: Crrent trends and future directions. Pain Manag. 2011;1:147-57
24. Clay F, Howett D, FitzGerald J, et al. Use of immersive virtual reality in the assessment and treatment of Alzheimer's disease: A systematic review. J Alzheimers Dis. 2020;75:23-43
25. Feng H, Li C, Liu J, et al. Virtual reality rehabilitation versus conventional physical therapy for improving balance and gait in Parkinson's disease patients: A randomized controlled trial. Med Sci Monit. 2019;25:4186-92
26. Ip HHS, Wong SWL, Chan DFY, et al. Enhance emotional and social adaptation skills for children with autism spectrum disorder: A virtual reality enabled approach. Computers & Education. 2018;117:1-15
27. Cooksey FS. Rehabilitation in vestibular injuries. Proc R Soc Med. 1946;39:273-78
28. Toupet M, Ferrary E, Grayeli AB. Visual analog scale to assess vertigo and dizziness after repositioning maneuvers for benign paroxysmal positional vertigo. J Vestib Res. 2011;21:235-41
29. Yardley L, Owen N, Nazareth I, Luxon L. Prevalence and presentation of dizziness in a general practice community sample of working age people. Br J Gen Pract. 1998;48:1131-35
30. Bergeron M, Lortie CL, Guitton MJ. Use of virtual reality tools for vestibular disorders rehabilitation: A comprehensive analysis. Adv Med. 2015;2015:e916735
31. van Vugt VA, Heymans MW, van der Wouden JC, et al. Treatment success of internet-based vestibular rehabilitation in general practice: Development and internal validation of a prediction model. BMJ Open. 2020;10:e038649
32. Józefowicz-Korczyńska M, Walak J, Szczepanik M. [Ocena zastosowania wirtualnej rzeczywistości jako metody fizjoterapii w uszkodzeniu obwodowym narządu przedsionkowego.] Otorynolaryngologia. 2014;13:51-57 [in Polish]
33. Rosiak O, Krajewski K, Woszczak M, Jozefowicz-Korczynska M. Evaluation of the effectiveness of a virtual reality-based exercise program for unilateral peripheral vestibular deficit. J Vestib Res. 2018;28:409-15
34. Lubetzky AV, Kelly J, Wang Z, et al. Contextual sensory integration training via head mounted display for individuals with vestibular disorders: A feasibility study. Disabil Rehabil Assist Technol. 2020 [Online ahead of print]
35. Sparrer I, Duong Dinh TA, Ilgner J, Westhofen M. Vestibular rehabilitation using the Nintendo® Wii Balance Board – a user-friendly alternative for central nervous compensation. Acta Otolaryngol. 2013;133:239-45
36. Givon Schaham N, Zeilig G, Weingarden H, Rand D. Game analysis and clinical use of the Xbox-Kinect for stroke rehabilitation. Int J Rehabil Res. 2018;41:323-30
37. Viirre E, Sitarz R. Vestibular rehabilitation using visual displays: Preliminary study. Laryngoscope. 2002;112:500-3
38. Pavlou M, Kanegaonkar RG, Swapp D, et al. The effect of virtual reality on visual vertigo symptoms in patients with peripheral vestibular dysfunction: A pilot study. J Vestib Res. 2012;22:273-81
39. Duque G, Boersma D, Loza-Diaz G, et al. Effects of balance training using a virtual-reality system in older fallers. Clin Interv Aging. 2013;8:257-63
40. Micarelli A, Viziano A, Micarelli B, et al. Vestibular rehabilitation in older adults with and without mild cognitive impairment: Effects of virtual reality using a head-mounted display. Arch Gerontol Geriatr. 2019;83:246-56
41. Park JH, Jeon HJ, Lim E-C, et al. Feasibility of eye tracking assisted vestibular rehabilitation strategy using immersive virtual reality. Clin Exp Otorhinolaryngol. 2019;12:376-84
42. Lee D, Hong S, Jung S, et al. The effects of viewing smart devices on static balance, oculomotor function, and dizziness in healthy adults. Med Sci Monit. 2019;25:8055-60

Indexed in: [Current Contents/Clinical Medicine] [SCI Expanded] [ISI Alerting System] [ISI Journals Master List] [Index Medicus/MEDLINE] [EMBASE/Excerpta Medica] [Chemical Abstracts/CAS]