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Original Article

Effectiveness of virtual reality therapy in chronic unilateral vestibular hypofunction: A randomized controlled study

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ABSTRACT

Objectives: The aim of the study was to investigate the superiority of rehabilitation with virtual reality (Nintendo Wii) over habituation exercises in chronic vestibular hypofunction.

Patients and methods: Eighty-seven patients (44 males, 43 females; mean age: 45.8±12.2 years; range, 19 to 70 years) with chronic unilateral vestibular hypofunction were included in the prospective randomized controlled study conducted between October 2017 and June 2018. Patients were randomized into two groups: the treatment group (TG; n=45) and the control group (n=42). Each group received vestibular rehabilitation exercises. The TG exercised with visual stimulation (virtual reality) in addition to the standard exercises. The patients were evaluated before the treatment and at two and three months. The frequency of dizziness was questioned. Visual analog scale, timed up and go test, Berg balance test, Romberg test, and Dizziness Handicap Inventory questionnaire were used to assess the patients.

Results: There was a statistically significant decrease in the severity of dizziness in both groups at two- and three-month controls (p<0.001). In the comparison between the groups, severity of dizziness, frequency of attacks, and daily frequency were significantly improved in the TG (p<0.001).

Conclusion: Adding virtual reality therapy to habituation exercises is effective in reducing the frequency of attacks.

Keywords: Chronic unilateral vestibular hypofunction, habituation exercises, vestibular rehabilitation, virtual reality, visual stimulation.

Chronic unilateral vestibular hypofunction is a clinical condition that develops as a result of deranged functioning of the right or left vestibular nerve. Often, vertigo is accompanied by symptoms such as nausea and imbalance.[1] A vestibular rehabilitation program is recommended for patients whose complaints persist for more than one month.[2] Vestibular rehabilitation is an exercise-based program. The literature yields increasing evidence for the use of vestibular rehabilitation in patients with vestibular disorders.

The aim of rehabilitation is to stabilize the gaze, provide postural control, and improve general physical condition.[3] Exercises are selected according to the type of vestibular loss, symptoms, and functional capacity. It has been reported that vestibular rehabilitation can improve secondary symptoms, such as fear of falling, dizziness, motion sensitivity, and nausea, and anxiety with central compensation mechanisms.[3] Since disorders such as anxiety and tension are common in patients with vestibular hypofunction, treatment is started with relaxation

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exercises.[4] The Cawthorne-Cooksey exercise program is an exercise program recommended for use in the treatment of certain vestibular disorders, such as unilateral vestibular hypofunction.[5]

Virtual reality is a three-dimensional simulation model with a dynamic environment that allows mutual communication created by computers. Virtual reality gives the person the feeling that the environment they are in is real. These features make it possible to use virtual reality in many fields, such as education, industry and aerospace engineering, and healthcare.[6] In recent years, the use of virtual reality therapy in neurorehabilitation, rehabilitation of muscle diseases, cardiac rehabilitation, orthopedic rehabilitation, geriatric rehabilitation, and psychiatric diseases has been increasing.[7]

Nintendo Wii (Nintendo Co. Ltd., Tokyo, Japan) is a game console that was released in 2006, used for virtual reality therapy. The Nintendo Wii is a remotely controlled wireless device designed to improve balance, muscle strength, and aerobic capacity. This device consists of a balance board and display screen. Nintendo Wii is a therapy method that allows self-study.[8] Burns et al.[9] reported in a study with healthy adults that Nintendo Wii games were well tolerated by individuals aged 21 to 65 years.

Few studies comparing virtual reality-based rehabilitation methods with traditional vestibular rehabilitation were reported in a recent systematic review. Additionally for these studies, the heterogeneity of subjects, such as population selection and protocol selection, has been mentioned.[10] Evidence-based examination of rehabilitation practices that have changed with the advancement of technology has gained importance in recent years. In light of this information, we designed this study on chronic unilateral vestibular hypofunction rehabilitation. The primary aim of this study was to investigate the superiority of rehabilitation with visual stimulation (Nintendo Wii virtual reality device) over habituation exercises in chronic vestibular hypofunction. The effects of virtual reality and habituation exercise treatments on dizziness severity, frequency, function, quality of life, and balance were evaluated.

PATIENTS AND METHODS

The prospective randomized controlled study was conducted at the Istanbul University Istanbul Faculty of Medicine, Department of Physical Medicine and Rehabilitation between October 2017 and June 2018. One hundred forty-three patients aged 18 to 65 years were assessed for eligibility. Patients with persistent vertigo for longer than one month despite the use of conservative treatment methods with follow-up in our clinic were included in this study. The diagnoses that caused dizziness in the patients included in the study were unilateral vestibular hypofunction, vestibular neuritis, Meniere's disease, age-related dizziness, and postsurgical or posttraumatic dizziness. Patients with centrally induced vertigo, orthostatic hypotension, psychosomatic disorder, advanced heart disease, cerebrovascular disease, migraine, malignancy, advanced cervical spondylosis on direct radiographs, history of major surgical intervention in the head and neck region, and patients who could not tolerate exercise were not included in the study. The study was initiated with 92 patients who met the inclusion criteria. However, a total of five patients could not proceed with the study due to move, dropout, or not presenting to follow-up (Figure 1). Consequently, 87 patients (44 males, 43 females; mean age: 45.8±12.2 years; range, 19 to 70 years) were included in the final analyses.

The patients were divided into two groups using the 1:1 randomization method: the treatment group (TG; n=45) and the control group (n=42). Only a home exercise program was applied to the control group, whereas a virtual reality rehabilitation program was applied to the treatment group in addition to the home exercise program. In the rehabilitation program with virtual reality, the games in the balance exercises group in the Wii Fit software of the Nintendo Wii device were selected. This group included the games “Soccer Heading,” “Slalom Ski,” “Penguin Slide,” “Tight Rope Walk,” “Snowboard Slalom,” “Ski Jumping,” “Table Tilt,” and “Balance Bubble” (Figure 2). The selection of the games was made in accordance with the literature, similar to the game groups preferred in virtual reality rehabilitation. All games in the system were played for 45 min two days a week for eight weeks, with a total of 16 sessions of visual stimulation.[11]

A home exercise program is an integral part of vestibular rehabilitation. Therefore, it was included in the protocol of both groups. In this study, the exercise protocol, which is a special form of Cawthorne-Cooksey exercises designed for patients with chronic unilateral vestibular hypofunction, was used.[2] The home exercise program was arranged for the patients at least five days a week for 30 min of two sets. In our study, the first session of exercise therapy was performed in the hospital under supervision in

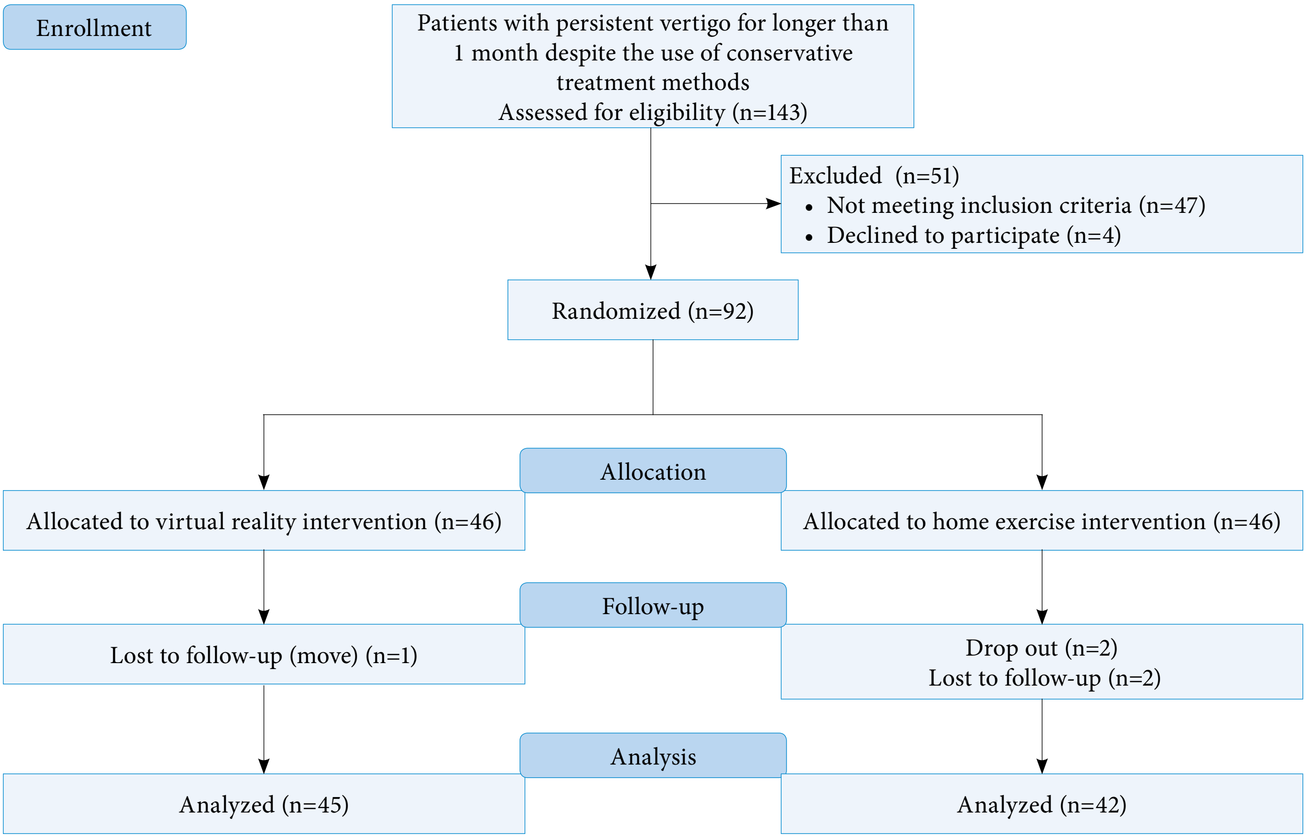

Figure 1. Flow diagram.

Figure 2. Virtual reality therapy.

both groups. The patients in the control group were followed up by phone calls once a week for motivation purposes. In addition, all patients were informed about the activities to be avoided. Participants were warned about possible side effects, such as increased dizziness, nausea, and falling after virtual reality and exercises. Mild nausea and dizziness were increased in two patients from the exercise group and one patient from the study group after the application. All these side effects were temporary, short-lived, and did not recur, thus the patients continued the study.

The Visual Analog Scale (VAS) was used to evaluate the severity of dizziness. The frequency of dizziness during the day and the frequency of dizziness felt in the last week were questioned separately using a three-point Likert scale (continuous, often, occasionally). Dizziness Handicap Inventory (DHI), timed up and go test (TUG), the Berg balance test (BBT), and the Romberg test were applied. All patients participating in the study were evaluated by the same investigator before treatment, after treatment (second month), and at one month after treatment (third month).

Visual Analog Scale is a frequently used scale to evaluate the severity of dizziness. The definition of the parameter to be evaluated is written on a 10-cm line (none/extreme or continuous), and patients are asked to mark their status. It has been reported in the literature that VAS is a useful scale for evaluating the severity of vertigo.[12]

Dizziness Handicap Inventory is a scale used in patients with dizziness and balance disorder, assessing the degree of impact on quality of life, emotional status, and functionality. Higher values indicate that the disorder is more severe. In scoring, 0 to 30 points indicate mild disability, 31 to 60 points indicate moderate disability, and 61 to 100 points indicate severe disability.[13,14]

The TUG test was used to evaluate functional mobility. In this test, the patient gets up from a sitting position, travels 3 m, and comes back within seconds. In this study, measurements were always made in the same environment and by the same person. For a correct assessment, the distance of 3 m was marked, and the patients used a standard armchair. The patients were walked with their accustomed shoes or assistive device, if any.[15]

The BBT is used to determine fall risk and evaluates patients during 14 different activities. In the BBT, a score of 0 is defined as "cannot perform," and a score of 4 is interpreted as "does independently and confidently." The maximum total score is 56, and higher scores indicate better balance.[16] The validity and reliability study of the Turkish version of the BBT was conducted.[17]

In the Romberg test, the patient is kept standing with their feet together and their arms at their sides. If the patient can remain stable, the patient is also asked to close their eyes. Deviation or shaking of the patient in one direction indicates a positive test. In peripheral vestibular diseases, it is observed that the patient falls significantly on the sick side.

Statistical analysis

The power analysis and sample size calculation were performed using the G*Power version 3.1.9.4 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) to ensure the adequate sample size for the independent samples t-test. A sample size of 92 patients was estimated depending on the probable effect size (d=0.8) at a power of 95% with a 10% drop probability.

Data were analyzed using IBM SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation or number and frequency. The distribution of study variables was checked with the Kolmogorov-Smirnov test.

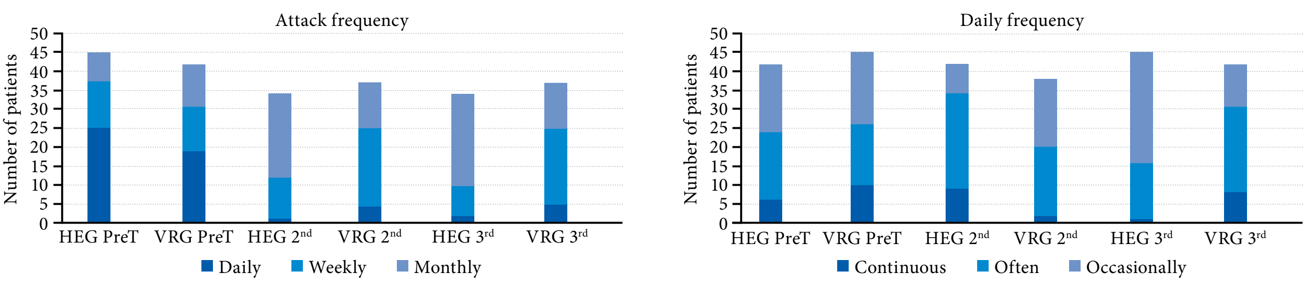

Figure 3. Attack frequency and daily frequency.

HEG: Home exercise group; VRG: Virtual reality group.

TABLE 1
Baseline parameters of the participants

	Virtual reality group (n=45)			Home exercise group (n=42)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			46.2±12.7			45.3±11.6	0.608
Sex							0.336
Female	20	44.4		23	54.8		
Male	25	55.6		19	45.2		
Education							0.122
Elementary	10	22.2		17	40.5		
Secondary	14	31.1		13	31.0		
University	21	46.7		12	28.6		
Occupation							0.459
Unemployed or retired	17	37.8		21	46.7		
Desk worker	21	46.7		17	40.5		
Physically demanding	7	15.6		4	9.5		
Attack frequency							0.439
Daily	25	55.6		19	45.2		
Weekly	13	28.9		12	28.6		
Monthly	7	15.6		11	26.2		
Daily frequency							0.594
Continuous	10	22.2		6	14.3		
Often	16	35.6		18	42.9		
Occasionally	19	42.2		18	42.9		
VAS score			8.08±1.34			7.45±1.85	0.108
TUG			11.42±2.02			12.07±2.34	0.183
Berg balance test			46.46±5.06			45.61±4.89	0.518
DHI			62.35±22.06			64.16±22.67	0.588

SD: Standard deviation; VAS: Visual Analog Scale; TUG: Timed Up&Go; DHI: Dizziness handicap inventory.

TABLE 2
Comparison of results between two groups

	Baseline (0)	2nd month (1)	3rd month (2)			Between-group differences at visit 0-2	
	Mean±SD	Mean±SD	Mean±SD	*p*	Post hoc	Mean±SD	*p*
Attack duration (min)							0.262
HEG	325.90±814.99	87.52±307.98	87.18±298.22	<0.001	<0.001$^{(0-1)(0-2)}$	238.71±831.34	
VRG	448.32±1123.81	10.07±28.68	10.07±24.81	<0.001	<0.001$^{(0-1)(0-2)}$	437.92±1104.10	
VAS							<0.001
HEG	7.45±1.85	4.92±1.93	3.37±1.55	<0.001	<0.001$^{(0-1)(0-2)}$	2.54±2.60	
VRG	8.08±1.34	3.20±1.67	3.37±1.55	<0.001	<0.001$^{(0-1)(0-2)}$	4.71±1.59	
TUG							0.086
HEG	12.07±2.49	9.21±1.35	9.19±1.31	<0.001	<0.001$^{(0-1)(0-2)}$	2.88±1.81	
VRG	11.44±2.05	8.02±1.51	8.02±1.35	<0.001	<0.001$^{(0-1)(0-2)}$	3.40±1.51	
BERG							0.997
HEG	45.70±4.98	51.59±3.44	51.88±3.46	<0.001	<0.001$^{(0-1)(0-2)}$	6.54±3.69	
VRG	46.50±5.11	53.42±2.54	53.48±2.58	<0.001	<0.001$^{(0-1)(0-2)}$	6.84±4.69	
DHI							0.147
HEG	65.14±22.59	38.47±19.75	37.57±19.59	<0.001	<0.001$^{(0-1)(0-2)}$	29.11±14.64	
VRG	63.00±22.58	30.97±18.35	29.77±18.82	<0.001	<0.001$^{(0-1)(0-2)}$=0.015$^{(1-2)}$	33.72±18.67	

SD: Standard deviation; HEG: Home exercise group; VRG: Virtual reality group; VAS: Visual Analog Scale; TUG: Timed Up&Go; DHI: Dizziness handicap inventory.

To compare between two groups, an independent samples t-test or the Mann-Whitney U test was performed for quantitative variables. Categorical variables were compared using the chi-square test. The Friedman test was used to make within-group comparisons. A p-value <0.05 was accepted to indicate statistical significance.

RESULTS

When the two groups were compared, there was no statistically significant difference in demographic data, such as sex, age, education level, and occupation, and in the initial evaluations, such as attack frequency, daily frequency, VAS, TUG, BBT, and DHI scores (Table 1).

In our study, there was a statistically significant decrease in the severity of dizziness evaluated by VAS in both groups at two- and three-month controls (p<0.001). In the comparison between the groups, there was a significant difference in the severity of dizziness evaluated by VAS in the treatment group compared to the control group (p<0.001). Statistically significant improvement was observed in both groups during the follow-up periods in DHI, TUG, BBT, daily frequency, and attack frequency at two- and three-month controls (p<0.001). Between the groups, it was determined that the frequency of attacks and daily frequency values were significantly improved in the treatment group compared to the control group (p<0.001, Figure 3), and there was no statistical difference between the groups in DHI, TUG, and BBT scores (Table 2).

DISCUSSION

The results suggest that virtual reality therapy is effective in reducing both the frequency of attacks during the day and the frequency of weekly attacks in vestibular rehabilitation. In the literature, daily frequency and attack frequency parameters are not frequently used evaluations in the follow-up of the effectiveness of vestibular rehabilitation. However, in the clinical follow-up of vertigo patients, using the frequency of attacks is frequently preferred. Therefore, we included the frequency assessment when planning this study.

In a study conducted with healthy volunteers in the literature, it was reported that visual information on the Nintendo Wii monitor helped to improve voluntary postural control in rehabilitation. Based on this, it was thought that virtual reality therapy could be effective in improving dynamic balance and reducing the risk of falling.[15] According to the results of this study, an improvement was observed in BBT with Cawthorne-Cooksey exercises, while virtual reality treatment did not have superiority in BBT. The effectiveness of virtual reality therapy on balance in patients with vestibular hypofunction is not clear. Therefore, studies with larger sample sizes are needed. Laufer et al.[11] examined the effectiveness of virtual reality therapy on balance in healthy elderly people in a review. They reported that there was improvement in TUG values in the virtual reality exercise group in all of the studies included in the review.[11] According to the results of our study, virtual reality therapy has no superiority over the TUG test in unilateral peripheral vestibular hypofunction rehabilitation.

Dizziness is one of the important problems affecting the quality of life for vertigo patients. In a study evaluating the effectiveness of Wii therapy on dizziness, Verdecchia et al.[18] reported that a vestibular rehabilitation program completed with Wii therapy was effective on dizziness in patients diagnosed with chronic unilateral vestibular hypofunction. According to the results of our study, virtual reality treatment has no superiority over dizziness. Verdecchia et al.[18] did not use a control group in their study, which may have led to the difference.

Considering that patient compliance, satisfaction, and participation are important in vestibular rehabilitation, as in the rehabilitation of other medical diseases, it can be said that virtual reality therapy stands out among rehabilitation approaches in this aspect. It is reported that the active participation of the patient in the treatment is more effective on motor learning and cortical reorganization, and rehabilitation with virtual reality therapy provides more feedback and motivation compared to traditional treatments.[19,20] Meldrum et al.[21] compared virtual reality (Nintendo Wii Fit Plus) treatment with conventional balance exercise in vestibular rehabilitation in patients with unilateral peripheral vestibular hypofunction. As a result of the study, the improvement of both groups was equal, while the virtual reality group reported better adjustment and satisfaction, less stress, and less fatigue.[21] A recent systematic review reports that rehabilitation with virtual reality therapy may have clinical benefits compared to traditional vestibular rehabilitation.[10]

The fact that the investigator who administered and followed the treatment in our study was not blind to the treatment groups is one of the factors limiting the power of the study. Due to the short follow-up period, the long-term effect of the rehabilitation program could not be evaluated. Additionally, the fact that the sample group of the study included more than one disease causing chronic unilateral vestibular hypofunction can be considered a limitation of this study. Despite all these limitations, the home exercise program being chosen as a subgroup of the Cawthorne-Cooksey exercise protocols specialized for patients with chronic vestibular hypofunction is an advantage of our study since, as far as we know, exercise protocols specialized for this disease were not used in randomized controlled studies investigating the effectiveness of virtual reality rehabilitation in the treatment of unilateral vestibular hypofunction.

In conclusion, in unilateral chronic vestibular hypofunction rehabilitation, significant improvements were observed in both groups in terms of the severity of dizziness and functionality and balance. However, the treatment group had better results regarding severity and frequency of dizziness. As a result of our study, while the importance of exercise in the rehabilitation of unilateral chronic vestibular hypofunction was revealed, it was determined that the addition of virtual reality therapy increased the effectiveness of rehabilitation. However, further studies with a longer follow-up are needed.

Ethics Committee Approval: The study protocol was approved by the Istanbul University Istanbul Faculty of Medicine Clinical Research Ethics Committee (date: 06.11.2017, no: 1260). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, control/supervision, critical review: A.K.; Design: A.K., Z.H.; Data collection and/or processing: Z.H.; Analysis and/or interpretation: T.S.; Literature review: Z.H., B.C.K.; Writing the article: Z.H., B.C.K., T.S.; References and fundings: T.S.; Materials: Z.H., B.C.K., T.S., A.K.

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