Case Report

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Interface between measures of benefit after vestibular rehabilitation – case report

Interface entre as medidas de benefício após a reabilitação vestibular – relato de casos

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ABSTRACT

The purpose of this research is to characterize the vestibular rehabilitation (VR), vestibulo-ocular reflex (VOR) gain, the occurrence of compensatory saccades, the static and dynamic balance, and the impact on quality of life in three patients with peripheral vestibular hypofunction. This is a descriptive study, approved by the ethics in research committee, under number 4,462.519. Three female patients participated in the study, two aged 55 and one aged 67, with a medical diagnosis of peripheral vestibular dysfunction. The participants underwent anamnesis, Dizziness Handicap Inventory (DHI) questionnaire, clinical assessment of postural balance and Video Head Impulse Test (vHIT), pre and post VR. The VR was applied in a personalized manner, based on the Cawthorne and Cooksey protocol, associated with virtual reality stimuli. After VR, a reduction in the total score average of DHI was observed, suggesting a decrease in participation restriction. The clinical balance assessment results were within the normal range for the altered tests, pre VR. In the three evaluated cases, vHIT showed increased RVO gain for the previously affected semicircular ducts (SCDs), compatible with normality standards, and reduction or extinction in the occurrence of compensatory saccades. The increase in VOR gain and the reduction or suppression of compensatory saccades after VR are suggestive signs of vestibular compensation. These results were compatible with increased postural stability and less restricted quality of life. These findings demonstrate the benefit provided by VR in the three evaluated cases.

Keywords: Rehabilitation; Virtual reality; Postural balance; Head impulse test; Case reports

RESUMO

Esta pesquisa teve como objetivo caracterizar o efeito da reabilitação vestibular (RV) sobre o ganho do reflexo vestíbulo-ocular (RVO), a ocorrência das sacadas compensatórias, bem como sobre o equilíbrio corporal e a qualidade de vida, em três pacientes com hipofunção vestibular periférica. Trata-se de um estudo descritivo. Participaram da pesquisa três pacientes do gênero feminino, duas com 55 anos e uma com 67 anos, com diagnóstico médico de disfunção vestibular periférica. As participantes foram submetidas à anamnese, questionário *Dizziness Handicap Inventory* (DHI), avaliação clínica do equilíbrio corporal e ao Vídeo Teste do Impulso Cefálico (vHIT), pré e após RV. A RV foi aplicada de forma personalizada, baseada no protocolo de Cawthorne e Cooksey, associada a estímulos de realidade virtual. Após a RV, observou-se a redução da média do escore total do DHI, sugestivo da diminuição na restrição de participação. Na avaliação clínica do equilíbrio obtiveram-se resultados dentro da normalidade para as provas alteradas, pré RV. Quanto ao vHIT, constatou-se aumento do ganho do RVO para os canais semicirculares anteriormente afetados, condizente com padrões de normalidade, e extinção ou diminuição de ocorrência das sacadas compensatórias, nos três casos avaliados. O aumento do ganho do RVO e a extinção ou redução das sacadas compensatórias, após a RV, evidenciam sinais sugestivos de compensação vestibular. Esses resultados mostraram-se compatíveis com o aumento da estabilidade postural e menor restrição da qualidade de vida. Os achados, em conjunto, demonstram o benefício proporcionado pela RV nos três casos avaliados.

Palavras-chave: Reabilitação; Realidade virtual; Equilíbrio postural; Teste do impulso de cabeça; Relato de caso

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INTRODUCTION

Body balance is achieved through harmoniously integrated sensory information from the visual, proprioceptive, and vestibular systems. Any conflict in this set may trigger dizziness, one of the most frequent complaints out of countless diseases and symptoms[1].

In most cases, dizziness results from changes in the vestibular system and impairs the quality of life of those affected by it[1,2]. Vestibular rehabilitation (VR) is an effective therapeutic option for indicated cases[2].

VR is the treatment of signs and symptoms related to vestibular dysfunction with exercises that stimulate the vestibular system and associated neuroplasticity mechanisms[1,2]. VR exercises aim to benefit visual, somatosensory, and vestibular interactions to improve visual and postural stability, even in face of conflicting sensory information[3,4].

Audiologists can complement conventional VR with immersive virtual reality. This therapeutic resource incorporates a wide range of stimuli with greater visual specificity and produces controlled sensory conflicts in a safe environment. Its main objective is to stimulate gains in the impaired vestibulo-ocular reflex (VOR) to achieve full vestibular system compensation[4]. Studies demonstrate the effectiveness of VR associated with immersive virtual reality to induce the adaptation of vestibular responses and help recover postural control[2,4].

The Vestibular Evidence Database to Guide Effectiveness (VEDGE)[5] and Orientation Guide for Speech-Language-Hearing Practices in Body Balance Assessment and Rehabilitation recommend using combined objective and subjective tests to assess and monitor VR results. Various clinical, functional, and instrumental tests have been broadly used in clinical and scientific practice, such as the Dizziness Handicap Inventory (DHI), Visual Analog Scale (VAS), Activities-specific Balance Confidence Scale (ABC-Scale), Timed Up and Go Test (TuG), Dynamic Gait Index (DGI), Video Head Impulse Test (vHIT), Computed Dynamic Posturography (CDP), Vestibular Evoked Myogenic Potential (VEMP), and so on.

VHIT stands out among the objective tests as a high-frequency, quick, and objective VOR assessment instrument that is not uncomfortable for patients[6]. VHIT individually assesses VOR gains in each semicircular canal (SCC) in the physiological frequency of angular head acceleration with short-amplitude and rapid-acceleration head impulses, providing lesion diagnosis information – e.g., affected SCC, degree of dysfunction, spontaneous nystagmus, and compensatory saccade, whose occurrence, amplitude, and latency parameters are objective indicators in vestibular compensation follow-up[6,7].

Most research that measures VR results is traditionally based on functional tests and/or self-assessment questionnaires that highlight important clinical measures. However, there is a gap in objective assessments of the vestibular system. Therefore, it is important to apply instrumental tests in combination with clinical and functional tests[8].

The objective of this study was to characterize the effect of VR on VOR gains, compensatory saccades, body balance, and quality of life in three patients with peripheral vestibular hypofunction.

PRESENTATION OF THE CLINICAL CASES

Procedures

This study is an observational prospective case series. It was approved by the Research Ethics Committee of the Onofre Lopes University Hospital (HUOL) (evaluation report no. 4.462,519) and conducted upon the recruited individuals' expressed agreement by signing an informed consent form.

The sample comprised three female patients, referred for VR by the HUOL otoneurology outpatient center. They were diagnosed with peripheral vestibular dysfunction due to hypofunction of one or more SCCs. Two of them were 55 and one was 67 years old, with histories of dizziness, imbalance, and/or falls.

The patients were submitted to otoneurologic clinical assessment by an otorhinolaryngologist, encompassing medical history, laboratory examinations specific to the case, and static and dynamic postural balance assessment tests. An audiologist conducted a basic audiological assessment (comprising pure-tone threshold audiometry, speech audiometry, and acoustic immittance) and vHIT and administered the DHI questionnaire.

DHI[9] was administered in interviews to measure the impact of dizziness on the patients' quality of life. It has 25 questions, divided into three domains: physical, emotional, and functional aspects. Each "yes" answer scores 4 points, each "sometimes" scores 2 points, and each "no" scores 0 points. The final score is the sum of all scores – the closer to 100 points, the greater the damage caused by dizziness in the patient's quality of life.

Balance was clinically assessed with the Romberg Test, Sharpened Romberg Test, and Fukuda Stepping Test[2]. In the Romberg Test, patients are instructed to take an orthostatic position, heels together at a 30º angle, looking forward, and then close their eyes for about 60 seconds. A positive examination means there is body sway, imbalance, and a strong tendency of falls. In the Sharpened Romberg Test, feet are aligned in a heel-to-toe position, and the analysis is like the previous one.

In Fukuda Stepping Test[2], individuals are required to gait, raising their knees to 45º, for 60 seconds to verify displacement with and without visual support. Cases of displacements greater than 50 centimeters or rotation greater than 30º are suggestive of vestibular changes.

VHIT[6] was conducted with ICS Impulse equipment and OTOsuite Vestibular software, manufactured by Otometrics, as part of the otoneurologic assessment (defined as pre-VR examination). After ending the treatment, the same researching audiologist made a new examination (defined as post-VR vHIT). VHIT results were analyzed together by the audiologists who participated in the research.

The reference values proposed by MacDougall et al.[6] and Hougaard were used in vHIT analysis, in which VOR gain ranges from 0.8 to 1.20 ms in lateral canals and from 0.7 to 1.20 ms in vertical ones. Abnormality can be indicated by small VOR gain and/or compensatory saccades[6,7].

The parameters used for compensatory saccades were occurrence, amplitude, latency, and organization. Latency was used to classify the saccades as covert (beginning before the end of the head movement, at a mean velocity between 70 and 100 ms) or overt (occurring after the head impulse, at a velocity greater than 100 ms)[10]. Saccade amplitude is specifically used to assess lateral SCCs, in which values higher than 100º/s indicate changes.

The percentage of saccade grouping is classified based on Perez and Rey Score (PR Score), whose objective is to measure compensatory saccade organization in time. Values range from 0 to 100 points – the higher the score, the greater the saccade dispersion. On the other hand, lower scores indicate greater grouping and saccadic organization, which in consonance with increased VOR gain indicates signs of vestibular compensation[10].

Then, the VR stage was conducted in the following order: neck relaxation and stretching exercises; Cawthorne-Cooksey exercises, involving progressive eye movements in combination with head and body displacement, such as bowing, sitting, standing, throwing a ball, and walking, with eyes open and closed[3]. Lastly, virtual reality stimuli were used in each session, based on the studies by Manso et al.[2].

VR exercises were customized according to each patient's complaints and physical condition[3]. They were instructed to do two types of exercises daily at home, with about 10 repetitions, twice a day. Each exercise was trained in the clinic, supervised by the research audiologist, and assisted by a companion, when necessary. The patients received a control sheet to record the daily exercises as positive visual reinforcement and a reminder to do them.

Virtual reality was trained with a Gear VR headset, manufactured by Samsung, model SM-R323 (2016). 3D technology in this device provides immersive 360º rotational experiences and photo and film visualization. Saccadic, optokinetic, and visual tracking stimuli were used[2], accessing the Samsung Gallery application along with virtual environment interaction, which simulated everyday situations, totaling 15 minutes per session of exclusive virtual reality.

Virtual reality stimuli were initially presented while patients were sitting, then walking on firm ground, followed by unstable ground (a cushion measuring 1.80x60x5), and lastly walking with head movements to make the training increasingly harder every session. The therapy lasted seven weekly 50-to-60-minute sessions. After ending the protocol, patients were submitted again to DHI, clinical balance tests, and vHIT; their cases were also reassessed by the otorhinolaryngologist.

Clinical case specificities

Case 1

Female aged 67 years and 7 months, nosologically diagnosed with persistent perceptual postural dizziness. She reported dizzy head sensation, imbalance, and daily vertigo episodes that lasted for some minutes, especially when she lay down on her left side. Symptoms had begun 5 years before and worsened over the preceding 4 months. The audiological assessment verified moderate sensorineural hearing loss in the right ear and moderate mixed hearing loss in the left ear, which occurred after perforating her tympanic membrane. She described bilateral tinnitus. Pre-VR vHIT identified bilateral vestibular hypofunction, with impaired anterior left and posterior right SCCs. She did not take any drugs for dizziness. Her comorbidities were systemic arterial hypertension (SAH) and osteoarthritis, which were being treated with drugs.

Case 2

Female aged 55 years and 9 months, nosologically diagnosed with Ménière's disease. She reported frequent imbalance and vertigo episodes, especially to the right side, lasting some days, aggravated by rapid horizontal and rotatory head movements, which had begun in adolescence and grew more intense in the preceding 15 days; these crises always alternated with symptomless periods. The audiological assessment identified mild sensorineural hearing loss in the right ear and normal auditory thresholds in the left ear. She reported tinnitus in the right ear. Pre-VR vHIT indicated bilateral vestibular hypofunction with impaired anterior left and posterior right SCCs. She took prescribed cinnarizine to control dizziness. Her pathological history included compensated SAH.

Case 3

Female aged 55 years and 5 months, nosologically diagnosed with Ménière's disease. She reported dizzy head sensation, gait deviation, and imbalance to the left side; she had already had falls and frequent vertigo episodes, lasting some hours or days. She related dizziness aggravation to head movements and turning in bed, but also said symptoms occurred without any changes in position. Symptoms had begun 5 years before, and the last episode had occurred 7 days before. The audiological assessment identified mild sensorineural hearing loss and tinnitus bilaterally. Pre-VR vHIT verified unilateral vestibular hypofunction with impaired anterior left SCC. She was instructed by her physician to stop taking antivertigo drugs when referred to VR. Her pathological history included SAH, osteoporosis, fibromyalgia, and depression; she took prescribed drugs for all these comorbidities.

Comparative description of test results in the study cases

DHI scores indicated that improved symptoms after VR reduced participation restriction in the assessed cases (Table 1).

Pre-VR body balance clinical assessment found changes only with eyes closed in the Sharpened Romberg Test (in the three clinical cases) and Fukuda Stepping Test (in cases 2 and 3). After the treatment, normal results were found in the tests that had been previously abnormal.

VHIT found changes in pre-VR VOR gain values, which indicate vestibular hypofunction in one or more SCCs. After RV, they increased back to normal values (Table 2).

There was a higher percentage occurrence of compensatory saccades before RV in lateral SCCs, which was reduced after the treatment. Moreover, the saccades totally stopped in the vertical canals, and the post-VR PR Score decreased considerably in the SCCs that had any saccade dispersion values before the therapy (Chart 1).

Table 1. Characterization of individual values obtained with the Dizziness Handicap Inventory in the study cases (n = 3)

Aspects	Case 1		Case 2		Case 3	
	Pre	Post	Pre	Post	Pre	Post
DHI – Emotional	12	2	12	4	18	6
DHI – Physical	16	6	18	4	22	8
DHI – Functional	18	4	18	6	20	8
DHI – Total	46	12	48	14	60	22

Subtitle: n = number of patients; DHI = Dizziness Handicap Inventory; Pre = before vestibular rehabilitation; Post = after vestibular rehabilitation

Table 2. Description of vestibulo-ocular reflex gain values in the study cases (n = 3)

Variable		Case 1		Case 2		Case 3	
		Pre	Post	Pre	Post	Pre	Post
VOR gain per SCC	LRSCC	1.03	1.16	1.13	1.2	0.96	1.24
	LLSCC	1.09	1.24	1.08	1.17	1.16	1.06
	PRSCC	0.48*	0.92	0.56*	0.96	0.77	0.88
	PLSCC	0.72	1.09	0.99	1.03	1.01	0.79
	ARSCC	0.86	0.8	0.8	1.14	0.9	0.95
	ALSCC	0.67*	0.81	0.61*	0.81	0.58*	0.83

*Abnormal value

Subtitle: n = number of patients; VOR = vestibulo-ocular reflex; SCC = semicircular canal; LRSCC = lateral right semicircular canal; LLSCC = lateral left semicircular canal; PRSCC = posterior right semicircular canal; PLSCC = posterior left semicircular canal; ARSCC = anterior right semicircular canal; ALSCC = anterior left semicircular canal

Chart 1. Characterization of the mean compensatory saccade occurrences, amplitudes, latencies, and grouping percentages Perez and Rey Score in the semicircular canals before and after the vestibular rehabilitation in the study cases (n = 3)

Saccades		Percentage occurrence (%)			Latency (ms)			Amplitude (°/s)			PR Score (%)		
Semicircular Canal		Pre	Post	Diff	Pre	Post	Diff	Pre	Post	Diff	Pre	Post	Diff
Lateral Right	Covert	70	0	-70	205	NA	-205	106	NA	-106	54	0	-54
	Overt	59	57.5	-1.5	357	303	-54	133	120	-13	42	38	-4
Lateral Left	Covert	22	0	-22	104	NA	-104	127	NA	-127	19	0	-19
	Overt	44	11	-33	307	256	-51	109	204	+95	10	0	-10
Anterior Right	Covert	0	0	0	NA	NA	NA	NA	NA	NA	0	0	0
	Overt	0	0	0	NA	NA	NA	NA	NA	NA	0	0	0
Anterior Left	Covert	0	0	0	NA	NA	NA	NA	NA	NA	0	0	0
	Overt	20	0	-20	422	NA	-422	182	NA	-182	0	0	0
Posterior Right	Covert	25	0	-25	96	NA	-96	209	NA	-209	21	0	-21
	Overt	25	0	-25	168	NA	-168	149	NA	-149	38	0	-38
Posterior Left	Covert	0	0	0	NA	NA	NA	NA	NA	NA	0	0	0
	Overt	28	0	-28	378	NA	-378	127	NA	-127	0	0	0

Subtitle: n = number of patients; % = percentage; ms = milliseconds; º/s = degrees per second; Pre = before vestibular rehabilitation; Post = after vestibular rehabilitation; Diff = Difference of the variable between before and after rehabilitation; NA = absence of saccades in that semicircular canal; PR Score = Perez and Rey Score

DISCUSSION

The study described three cases of women with peripheral vestibular dysfunction due to SCC hypofunction; two of them were 55 and one was 67 years old. The main complaints were vertigo, dizzy head sensation, imbalance, and falls. SAH, osteoarthritis, and osteoporosis were predominating comorbidities.

Vestibular dysfunction is reportedly more prevalent in females about 60 years old. Such indices increase with age, exposure to metabolic and hormonal changes, and greater attendance to health services[2]. SAH is reported in the literature as one of the main circulatory problems that impair inner ear oxygenation and cause changes in the vestibular system[11]. Musculoskeletal disorders are explained by the association of dizziness with other common geriatric conditions; in these cases, dizziness results from multifactorial disorders, impacting their confidence to perform activities of daily living that require balance[12].

Differences between pre and post-intervention DHI scores are significant when they are greater than 18 points[2]. This is compatible with the results in this study, which points to DHI as an important tool to monitor dizziness-related participation restriction, diminishing the impact of symptoms on their quality of life.

Clinical balance assessment findings identified less visual dependence in static and dynamic postural control, especially with eyes closed. Vestibular responses were adapted after VR, indicating recovered postural stability[11].

Post-VR vHIT results indicated increased VOR gains in SCCs affected by vestibular hypofunction – which agrees with normal values, fewer compensatory saccade occurrences, and PR Scores. These findings confirm that vHIT was an appropriate instrument to monitor post-VR VOR gain and objectively characterize the signs indicative of vestibular compensation[12,13].

Saccade occurrence, amplitude, latency, and PR Score tend to decrease as VOR gain increases, due to the close relationship between the vestibular and saccadic systems[14]. Reduced latency suggests that the brain learned to interpose saccades while recovering from the lesion. This is considered an important predictor to monitor vestibular compensation progress[13] and explains the disappearance of compensatory saccades in vertical SCCs and the reduction or disappearance of saccades in lateral SCCs after VR in this study.

The greater occurrence of saccades in lateral SCCs in this study is due to the greater head impulse velocity necessary to perform the test in these canals, which also generates higher amplitude values than in the vertical canals[15].

Compensatory saccades maintained in the lateral left SCC, though with normal VOR gain values, indicate compensated clinical vestibular hypofunction after VR[15].

VHIT data, in combination with reduced symptomatology, revealed that increased VOR gain is directly related to dynamic visual acuity stabilization – which is one of the main objectives of VR[13-15].

It is also important to highlight the importance of doing VR exercises systematically and daily. Vestibular compensation depends on neuroplasticity phenomena, such as habituation (brought about by repetitive exercise stimulation), adaptation (such as VOR and vestibulospinal reflex gain readjustments), and substitution of absent or irregular vestibular responses with eye movement systems to compensate for existing deficits[2,4].

There is no consensus on the number of therapy sessions with immersive virtual reality in combination with traditional VR needed for discharge. The consulted literature ranges considerably from six to 10 sessions [4]. Immersive virtual reality can lead to greater adherence to exercises and is described as a motivating and pleasant element that helps reduce the number of sessions[4,8].

Lastly, it is important to use combined instrumental, clinical, and functional tests to assess and monitor treatment effects on vestibular function and body balance. They provide objective vestibular compensation markers and support evidence-based otoneurologic and speech-language-hearing clinical practice[5,8].

Future studies should have larger samples to conduct original research. It is also important to longitudinally follow up with such patients, given that some diseases that affect the vestibular system may fluctuate and relapse.

FINAL COMMENTS

After VR, VOR gain increased to normal values, and compensatory saccades disappeared or partially decreased, as well as the PR Score, demonstrating signs suggestive of vestibular compensation. These results were compatible with increased postural stability in clinical balance tests with eyes closed and decreased the impact of vestibular symptoms on the patients' quality of life.

Altogether, the findings of these clinical, functional, and instrumental tests demonstrate the benefits provided by VR to the three study cases.

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