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ORIGINAL ARTICLE

Outcomes After Vestibular Rehabilitation and Wii® Therapy in Patients With Chronic Unilateral Vestibular Hypofunction☆

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Abstract
Introduction and objectives: Vestibular rehabilitation therapy is an exercise-based programme designed to promote central nervous system compensation for inner ear deficit. The objective of the present study was to analyse the differences in the perception of handicap, the risk of falls, and gaze stability in patients diagnosed with chronic unilateral vestibular hypofunction before and after vestibular rehabilitation treatment with complementary Wii® therapy.
Materials and methods: A review was performed on the clinical histories of patients in the vestibular rehabilitation area of a university hospital between April 2009 and May 2011. The variables studied were the Dizziness Handicap Inventory, the Dynamic Gait Index and dynamic visual acuity. All subjects received complementary Wii® therapy.
Results: There were 69 cases (41 woman and 28 men), with a median age of 64 years. The initial median Dizziness Handicap Inventory score was 40 points (range 0–84, percentile 25–75=20–59) and the final, 24 points (range 0–76, percentile 25–75=10.40), $P<.0001$. The initial median for the Dynamic Gait Index score was 21 points (range 8–24, percentile 25–75=17.5–2.3) and the final, 23 (range 12–24, percentile 25–75=21–23), $P<.0001$. The initial median for dynamic visual acuity was 2 (range 0–6, percentile 25–75=1–4) and the final, 1 (range 0–3, percentile 25–75=0–2), $P<.0001$.
Conclusion: A reduction was observed in the Dizziness Handicap Inventory Values. Values for the Dynamic Gait Index increased and dynamic visual acuity improved. All these variations were statistically significant.

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PALABRAS CLAVE
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Resultados tras la rehabilitación vestibular y terapia Wii® en pacientes con hipofunción vestibular unilateral crónica

Resumen
Introducción y objetivos: La rehabilitación vestibular está destinada a maximizar la compensación central de la enfermedad vestibular periférica. El objetivo del presente estudio fue analizar las diferencias de la percepción de discapacidad, el riesgo de caídas y la estabilidad de la mirada antes y después de un tratamiento de rehabilitación vestibular con el uso complementario de terapia Wii® en pacientes con diagnóstico de hipofunción vestibular unilateral crónica.
Materiales y métodos: Se revisaron registros de pacientes entre abril de 2009 y mayo de 2011 del área de rehabilitación vestibular de un hospital universitario. Las variables estudiadas fueron el *Dizziness Handicap Inventory*, el índice dinámico de la marcha y la agudeza visual dinámica. Todos los sujetos usaron Wii® como complemento.
Resultados: Sesenta y nueve casos (41 mujeres y 28 hombres). La mediana de edad fue 64 años. La mediana de *Dizziness Handicap Inventory* inicial fue de 40 puntos (rango 0-84, percentil 25-75 = 20-59) y final de 24 (rango 0-76, percentil 25-75 = 10-40) $p < 0,0001$. La mediana del índice dinámico de la marcha inicial fue 21 puntos (rango 8-24, percentil 25-75 = 17,5-23) y final de 23 (rango 12-24, percentil 25-75 = 21-23) $p < 0,0001$. La mediana de la agudeza visual dinámica inicial fue 2 (rango 0-6, percentil 25-75 = 1-4) y final de 1 (rango 0-3, percentil 25-75 = 0-2) $p < 0,0001$.
Conclusión: Se observó una disminución de los valores del *Dizziness Handicap Inventory*, un aumento de los valores del índice dinámico de la marcha y una mejoría en la agudeza visual dinámica; todas estas variaciones fueron estadísticamente significativas.

Introduction

Individuals with dysfunction in the vestibular system (vestibulopathy) present symptoms of dizziness, vertigo, visual disturbances and problems with physical balance that affect their lives negatively.

In the 1940s, Cawthorne and Cooksey[1] laid the foundations of vestibular rehabilitation (VR). Later on, various groups of researchers backed VR scientifically as an effective treatment for this group of patients, using laboratory and clinical trials.

In 2007 Hillier and Hollohan[2] carried out a systematic review on VR in unilateral peripheral vestibular dysfunction, and concluded that there is moderate to strong evidence that VR (exercises based on movement) is a safe and effective method for patients with unilateral peripheral vestibular dysfunction. This was based on 9 moderate to high quality studies that compared VR with placebo, or another form of non-vestibular rehabilitation. In 2011 these authors brought the review up to date, analysing 27 randomised clinical trials and obtaining similar results.[3]

With its own specific assessment tool (battery of clinical examinations and functional tests), VR has a group of exercises designed to maximise the central compensation of the peripheral vestibular disorder.[4] Adequate compensation can be achieved, especially if perfect, complete integration of proprioceptive and visual information is produced.[5]

The video game console Wii®, of the Nintendo brand (Japan), was designed for family entertainment. It consists of a console and a control (Wii® remote) with 3 accelerometers that capture acceleration in the 3 dimensions of space and send the information via a Bluetooth signal to a sensor bar located below the screen (TV). It makes it possible to perform movements of the upper limb that are transmitted to the game in real time. In addition, it has an accessory, the Balance Board, which is a platform with 4 pressure sensors that send a signal of the same characteristics as the Wii® remote and allows playing games while standing up on it. An example is the game Wii® Fit Plus, which makes it possible to train your balance and stimulate cognitive, visual and postural responses.[6] We do not know if this technology, for recreational use, can interfere with the results of vestibular therapy if the technology is utilised as a complement to the therapy. The objective of our study was to analyse the differences in the perception of disability, the risk of falls and gaze stability of gaze stability before and after conventional VR therapy using Wii® as a complement to treatment in patients with a diagnosis of chronic unilateral vestibular hypofunction.

Materials and Methods

Participants

We reviewed the records of patients treated in the area of VR in the kinesiology service at a university teaching hospital between April 2009 and May 2011, that presented chronic unilateral vestibular hypofunction; the condition was considered chronic when the patients presented symptoms for more than 2 months.[7,8] The patients were referred to our area from vestibular sector of the otorhinolaryngology service at 2 university hospitals in the Autonomous City of Buenos Aires. All of the subjects were assessed with complete otoneurological and medical history performed by a medical otoneurological specialist with 15 years of experience in the speciality, who referred the subjects to the area of rehabilitation. Medical diagnoses were vestibular neuronitis, acute cochleovestibular failure, labyrinthitis, postoperative acoustic neurinoma, endolymphatic hydrops (with more than 3 months without crisis), post-intratympanic gentamicin and non-specific chronic vestibulopathy. All patients had videonystagmography reports with caloric tests showing a decrease in greater than 25%, and were classified as right or left vestibular hypofunction. Patients reported symptoms of dizziness aggravated by the environment and cephalic movement (optokinetic stimuli), instability and insecurity in their gait and fear of falling. For the analysis, we included records of patients with complete results (before/after) from the dynamic gait index (DGI), the clinical dynamic visual acuity (DVA) test and the Dizziness Handicap Inventory (DHI) and that had used the Wii® in their rehabilitation as a complement. We excluded cases with incomplete follow-up, associated signs of central vestibular lesion, associated benign paroxysmal positional vertigo, antecedents of joint replacement in the lower limbs and with severe neurological and locomotor problems.

Variables Studied

Dynamic gate index (DGI) was assessed at the beginning and end of treatment. This test was developed by Shumway-Cook and Woolacott[9] to assess the ability to change gait when there are different external orders and obstacles. It consists of 8 tests with a score of 0 (poor) to 3 (excellent), including gait at a comfortable speed, gait with changes in speed, and gait while rotating the head, turning, going over and around obstacles and climbing stairs. The result range is from 0 to 24 points. Results lower than 16 indicate a high risk of falls; the cut-off value is considered to be 19 points. The DGI has shown good inter-evaluator reliability (0.96) and test-retest reliability (0.98); it is a valid predictor of falls in the older adult population.[10] There is a moderate correlation between the DGI and Berg balance scale evaluated in patients with vestibular disorders, but the DGI is a more sensitive assessment tool in patients with this disorder.[11] In contrast, Wrisley et al.[12] reported that the DGI should be used with precaution due to a lack of strong reliability. However, Whitney et al.[13] reported that the DGI can be a good indicator of risk of falls in patients with vestibular problems, regardless of age.

Gaze stabilisation during cephalic movement (vestibulo-ocular reflex) was assessed with the clinical DVA test. To do so, the Good-Lite® optotype Chart R in proportionally-spaced LogMar sizes ETDRS was used. This test detects abnormalities when high frequencies (1.5 or 2 Hz) are used, as compared to frequencies of 0.5–1 Hz.[14] Patients were seated in front of the optotypes chart, placed at 3 m from the back of the chair. First of all, the therapist recorded the lowest line that the patient was able to read with his or her head still, without making any mistakes, with the patient reading at a speed of 1 optotype per second. Next, the therapist held the patient's head with both hands on the sides of the head, with a head flexion of 30° to place the lateral semicircular canal in the horizontal plane. In this plane, movements of 20° towards each side were used at a frequency of 2 Hz (the complete range of movement of 40° should be performed in 1 s). The therapist recorded the lowest line that the patient was able to read while his or her head was in movement, with the same requirements as when the head was still. Normal value was considered to be up to 2 lines of difference between the static visual acuity (head still) and the dynamic visual acuity (head in movement); values of 3 or more were considered abnormal. This difference was recorded as a study variable. To reduce operator error, a metronome and a similar device described by Dannenbaum et al.[15] were used; the researchers' device consisted of a transparent plastic rectangle that had a drawing of a 40°-angle oriented towards the front, with a central line that separated it into 2 equal parts of 20° on each side, held by a support to the floor. This central line was aligned with a mark placed on the sagittal plane of the patient's head without touching it, which made it possible to respect the range of movement (Fig. 1).

Figure 1 Device to regulate the range of movement in the performance of the clinical dynamic visual acuity test. Source: adapted from Dannenbaum et al.[15]

Perception of disability was assessed with self-administered questionnaire known as the Dizziness Handicap Inventory (DHI), which was described by Jacobson et al.[16] in 1990 and validated to Spanish by Pérez et al.[17] in 2000. It consists of 25 questions that evaluate the functional, physical and emotional aspects related to dizziness and instability, with a score ranging from 0 to 100, with the greater the score, the greater the degree of perception of disability. The DHI has high reliability and internal consistence (Cronbach's alpha=0.89), as well as high test-retest reliability (Pearson's correlation coefficient=0.97).[16]

At the end of treatment, all of the patients reported the perception of change in their problem using a post-therapy symptom scale (PTSS) designed by Shepard et al.[18] The value 0 indicated ''no symptoms''; 1, ''marked improvement''; 2, ''mild improvement with persistence of

Table 1 Wii® Games Used as a Complement in Vestibular Rehabilitation.

Game	Action
Wii Fit® Plus Platforms	Stimulate ankle strategy in multiple directions
Wii Fit® Plus Tilting	Stimulate standing balance with rapid cephalic movements
Wii Fit® Plus Bicycle	Stimulate dynamic balance (gait in place) and stimulate optokinetic and saccadic reflexes
Wii Sport® Bowling	Displacement of the centre of gravity forwards, down and back. Global physical coordination and balance
Wii Play® Target practice	Stimulate ocular movements: saccadic motions, ocular fixation and slow following Eye-hand coordination

symptoms''; 3, ''no changes''; and the maximum value of 4 indicated that ''symptoms worsened after the therapy''.

Treatment

Treatment consisted of exercises of adaptation, and/or habituation and/or substitution depending on each case, determined and adapted based on individual assessment. There were also 5 games from the Nintendo Wii® video game console for 20 min twice a week until the end of treatment. The games used (Table 1) were platforms, tilting, bicycle (Wii® Fit Plus), bowling (Wii® Sport) and target practice (Wii® Play). All of the subjects performed exercises of adaptation of the vestibulo-ocular and vestibulo-spinal reflexes 3–5 times a day in their homes, with a total stimulus time of 20–40 min daily. The vestibulo-ocular and oculomotor exercises included paradigm X1 and X2 (near and far) and the exercises 2 cards, card memory, saccadic movements and gaze shifting. The vestibulo-spinal exercises included balance with progressive reduction of the holding base, eyes open and closed and firm to soft surface. The gait exercises included in tandem, with eyes closed, with cephalic movement in the sagittal and horizontal planes, speed changes and turns. Habituation exercises were indicated based on the result of the 16 movements in Neil Shepard's[18] motion sensitivity quotient. The movements chosen for habituation were performed as follows: 4 repetitions 4 times a day, until the exercises did not generate any symptoms for 48 h, at which time the patients suspended them. Table 2 presents a description of the treatment protocol. The VR exercises were based on the protocols of Susan Herdman.[19]

Statistical Analysis

Descriptive statistics were used for the characteristics of the population studied. The pre- and post-treatment were carried out using Wilcoxon signed rank test. A value of $P \leq .05$ was considered significant. The statistical program SPSS v. 17 was used for the analysis.

Table 2 Treatment Protocol.

	Sessions	Programme of at-home exercises
Initial assessment	Personal clinical history Oculomotor assessment Vestibulo-ocular assessment: − Cephalic impulse test − Cephalic saccades test (video Frenzel system) − Clinical dynamic visual acuity test Sensitivity in lower limbs and coordination Dizziness Handicap Inventory Dynamic gait index Indication for adaptation and/or habituation and/or substitution exercises according to assessment Patient education	1 or 2 exercises 3 times a day based on tolerance Stimulate the progressive return to daily activities Recommend guidelines to prevent falls in the home
Follow-up	Review at-home exercises Progress exercises in time and speed Incorporate Wii exercises according to tolerance, progress up to 30 min per session	Increase the number of exercises Increase time and speed in the exercises Progress to 5 times a day Emphasis on gait speed
Final assessment	Physical assessment and review of symptoms (the same as in the initial evaluation) Post-therapy symptom scale Report for referring physician	Reinforce recommendations for the home on prevention of falls and return to normal activities Emphasis on maintaining physical activity appropriate for patient age

Table 3 Time With Symptoms and Number of Sessions.

		Time with Sts	Sessions
Mean		14.46	13.03
Average		12.00	10.00
Standard deviation		10.141	7.227
Minimum		2	5
Maximum		48	50
Percentiles	25	6.00	10.00
	50	12.00	10.00
	75	21.00	15.00

Sts: symptoms; Time: expressed in months.

Results

A total of 107 kinetic records were reviewed and 38 were excluded; the reasons were as follows: for incomplete follow-up (18), associated PTSS (13), antecedents of joint replacement in lower limbs (2), locomotor problems (4) and for severe neurological conditions (1). An analysis was performed to assess the changes in perception of disability, risk of falls and gaze stability after the rehabilitation programme complemented with Nintendo® Wii games. We studied 69 cases. Median age was 64 years (range=19–84, percentile 25–75=50–69). The number of females was 41 (59.4%) and that of males was 28 (40.6%). The evolution time of the symptoms and number of sessions carried out is shown in Table 3. There were no significant differences between the diagnoses of right vestibular hypofunction (n=36, 52.2%) and left (n=33, 47.8%). Table 4 presents the distribution of the measurements for DHI, DGI and DVA at the beginning and end of treatment. No patients classified their post-therapy state with a 4 (feeling worse) in the PTSS (Table 4). Pre- and post-treatment comparisons of the perception of disability measured by the DHI, risk of falls measured by the DGI and gaze stability measured by the DVA were statistically significant (shown in Table 5).

Discussion

This article presents the results obtained from a VR plan, to which the complementary use of video game equipment for recreational use (non-conventional from the medical point of view) was added. Using video games is currently being studied by the scientific community as a therapeutic recreational tool. Subjects with chronic vestibular symptoms develop alterations in the emotional sphere, such as anxiety and depression.[20] Rosenberg et al.[21] suggest that the games known as exergames, Nintendo's Wii® among them, may represent a new pathway for improving depressive symptoms in the elderly.

Table 5 Comparisons of the Variables Studied Before–After Rehabilitation.

	Initial DHI–final DHI	Initial DGI–final DGI	Initial DVA–final DVA
Z[a]	−5.194	−5.919	−4.420
P	.0001	.0001	.0001

DGI: dynamic gait index; DHI: Dizziness Handicap Inventory; DVA: dynamic visual acuity.
[a] Wilcoxon signed rank test.

From a rehabilitation focus, we were interested in being able to classify patients from a functional aspect, not an aetiological one. For that reason, the criterion for including patients was presenting a reduction of the unilateral vestibular function, regardless of its aetiology; the exercise plan was the same for a vestibular neuronitis and an acoustic neurinoma surgery, because both shared the unilateral vestibular hypofunction. The programme for rehabilitation varied among subjects, as it was organised based on individual functional assessment, not on aetiology.

In 2010 Clark et al.[22] validated the use of the Wii® Balance Board platform for assessing physical balance, comparing it with a strength platform from a biomechanical laboratory, and they suggested using the Wii® Fit Plus game as an assessment tool. Then, in 2011, these authors obtained reliable results with 23 participants (intraclass correlation coefficients between 0.81 and 0.88) in the use of 2 Balance Boards connected to special software, to register the asymmetry of weight load and the centre of pressure between Day 1 and Day 2 of measurement.[23] Graves et al.[24] found greater satisfaction after using different Wii® Fit games in 3 populations (adolescents, young adults and elderly adults) as compared with using video games that used only a manual control. The Wii® games that included aerobic and balance activities obtained an average of 80% satisfaction. Later on, Reed-Jones et al.[25] recommended using the Wii® Fit balance test as complementary information, but not just by itself. We found a publication on injuries provoked by the use of this technology in the general population: fracture

Table 4 Distributions of the Results Before and After Rehabilitation.

		Initial DHI	Final DHI	Initial DGI	Final DGI	Initial DVA	Final DVA	PTSS
Mean		40.30	26.43	19.78	21.88	2.62	1.72	1.17
Average		40.00	24.00	21.00	23.00	2.00	1.00	1.00
Standard deviation		23.935	20.137	3.674	2.704	1.758	1.756	.747
Minimum		0	0	8	12	0	0	0
Maximum		84	76	24	24	6	7	3
Percentiles	25	20.00	10.00	17.50	21.00	1.00	.00	1.00
	50	40.00	24.00	21.00	23.00	2.00	1.00	1.00
	75	59.00	40.00	23.00	24.00	4.00	2.00	2.00

DGI: dynamic gait index; DHI: Dizziness Handicap Inventory; DVA: dynamic visual acuity; PTSS: post-therapy symptom scale.

of the base of the 5th metatarsal, shoulder injuries, traumatic hemothorax (fall during the use), dislocations and head trauma (provoked by a fellow game-player).[26] However, the incidence was low and related to incorrect use of the technology (generally with excessive use), although implementing this technology could be accompanied by a harness anchored to the ceiling, as Sparrer et al.[27] did in their recent work to reduce the risk of falls during game practice. They did not register collateral effects from using this technology in subjects with a diagnosis of vestibular neuronitis; the results indicated favourable effects for recovery in this patient group, but their subjects (in contrast to the patients in our study) were only trained with the console games for 10 weeks and did not use VR exercises. The results presented by Gatica et al.[28] confirmed that programmed training with the Wii® Fit Plus for older adult patients with balance disorders showed substantial changes in the variables of mean speed and displacement of the centre of pressure (COP) in standard and tandem posturographic modes following 8 weeks of treatment.

The use of this technology was widely accepted by our patients in this study, similar to what was obtained by Meldrum et al.[29] in 2011, when they evaluated the ease with which patients with vestibular problems and other central neurological disorders used the Nintendo Wii® Fit Plus. Those authors reported that 88.5% of the patients would like to use this tool in future treatments, and no patient suffered a fall during its use. In our study, none of the patients reported being worse after the treatment, and no falls were registered during the study period. Only 3 patients reported not obtaining changes after the therapy, as measured by the PTSS; 2 did not present perception of disability, increase in risk of falls and alteration of the DVA in both assessments (pre- and post-therapy), while the third patient maintained a severe perception of disability (initial DHI of 82 and final of 68), without an increase in risk of falls but with persistence of alteration of the DVA at the end of treatment. The first 2 had greater permanence of symptoms at 2 years and the last patient, at 18 months.

At the beginning of this study, we did not include cultural validation of the DHI in our country, so the Spanish version was used. The Argentinean version was recently published by Caldara et al.[30] after we had collected our data. Both DHI versions are similar and we feel that this had no effect on the results of our analysis.

Using this technology in combination with conventional exercises included in a VR programme did not allow us to differentiate the results separately. The post-therapy improvement obtained is similar to that of prior studies published by other authors, who assessed the efficacy of different VR protocols in patients with chronic unilateral vestibular hypofunction without the use of video games. Consequently, a limitation of our study is not differentiating the contribution of the Wii® games in the benefits found after treatment. However, we do know that the challenges of a complex visual setting are important in the compensation of a unilateral vestibular hypofunction, so this type of video games could help to generate settings enriched with sensory stimuli, similar to virtual reality. Furthermore, the fact that the majority of the patients preferred the Nintendo Wii® Fit Plus with the conventional treatment could have implications for patient compliance with exercise.[29]

Future controlled and randomised clinical trials are needed to evaluate the benefits of Wii® therapy in patients with vestibular disorders.

Conclusion

In our study a decrease was observed in the perception of disability, an increase in the values of dynamic gait index and an improvement in gaze stability after the treatment, with all these variations being statistically significant. We cannot recommend exclusive use of the video game console as a treatment tool. Nevertheless, its use did not cause complications or reduction in the benefits of the conventional VR exercises utilised with our patients, and probably helped in complying with the exercise programme.

Conflict of Interests

The authors have no conflicts of interests to declare.

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