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A Comparison Between Oculomotor Rehabilitation and Vestibular Electrical Stimulation in Unilateral Peripheral Vestibular Deficit

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Abstract: Rehabilitation therapy is proved to be effective in reducing disability in patients with persistent symptoms of disequilibrium after acute unilateral peripheral vestibular deficit. The aim of this study was to evaluate the effects of oculomotor rehabilitation (group 2) on static balance and a dizziness handicap and to compare those with the effects to vestibular electrical stimulation (group 1). Before and after therapy, we tested 28 patients, using static posturography and the dizziness handicap inventory short form. After therapy, all subjects reported a reduction of symptoms ($p = .00019$). In group 1, the reductions seen in eyes-opened length of the oscillations and eyes-opened and eyes-closed surface of the body sway were statistically significant, respectively ($p = .04$; $p = .02$; $p = .02$). Group 2 patients revealed better stability on all parameters, and the reductions of eyes-opened length and of eyes-opened correlation function between length and surface were statistically significant ($p = .01$ and $p = .01$, respectively). Analysis of the equilibrium system subcomponents did not show any variation. Oculomotor exercises, employed in most rehabilitative protocols and including head movements to improve vestibular adaptation, have proved to reduce the perceived overall impairment and postural sway in patients with recent unilateral vestibular disorders, even though the disorders are not associated with head movements. Comparison of our two study groups did not show any significant difference, revealing that both forms of therapy are effective.

Key Words: Dizziness Handicap Inventory; oculomotor rehabilitation; posturography; static balance; unilateral peripheral vestibular deficit; vestibular electrical stimulation

Unilateral peripheral vestibular deficit is one of the most frequent disorders affecting the equilibrium system. Although clinical experience suggests that, after the acute phase, recovery of gaze and postural stability often is possible without specific exercises, some patients have a prolonged recovery period, do not return to all normal activities, or continue to have subjective symptoms of disequilibrium [1].

In reducing disability caused by peripheral vestibular lesions, rehabilitation is proved to be an effective method by facilitating central nervous system compensation [2–4]. Goals of rehabilitation are, therefore, the reduction of the severity of the symptoms and the improvement of functional balance, physical mobility, and overall activity level.

In 1990, Cesarani et al. [5] proposed to treat patients with unilateral vestibular deficit with vestibular electrical stimulation (VES). VES is a noninvasive technique that provides nerve or muscle stimulation (or both) via surface electrodes placed on the paravertebral nuchal muscles opposite the impaired vestibular side. The electrical stimulation facilitates the contralateral impaired vestibular nuclei by the crossed spinovestibular pathway,

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decreasing the duration of total disability and supporting compensation. The evidence of its central and peripheral action comes from neurophysiological studies [6,7], from demonstration of the soleus H reflex modification produced by transcutaneous vibration of the Achilles tendon [8], and from an improvement of left visuospatial hemineglect in patients suffering from extensive right-hemisphere lesions [9].

Among the mechanisms that contribute to the recovery of vestibular responses, vestibular adaptation plays an important role, owing to the plasticity of the vestibular system. Most of the exercises used in vestibular rehabilitation protocols aim to improve this mechanism by inducing retinal slip during head movements [10]. Shelhamer et al. [11] suggested that head movements are not essential for adaptation and showed a key role of visual stimulations evoking optokinetic nystagmus or smooth pursuit. Visual and optokinetic stimulations act on the entirety of the structures controlling posture, gaze, and spatial cognition. Also, visually guided saccades have been employed in vestibular rehabilitation in determining stabilization of body sway [12,13]. Repeated optokinetic stimulation was found to facilitate recovery from vestibular deficits [14,15]. The purpose of this study was to analyze the effects—on static balance and dizziness handicap—of oulomotor rehabilitation (adopting foveal and full-field stimuli) in patients affected by peripheral vestibular lesions and to compare those results with the effects of VES.

PATIENTS AND METHODS

We enrolled in the study 28 patients (20 women, 8 men; mean age, 59 ± 6 years) from 1 to 6 months after the acute phase of unilateral vestibular deficit. All had received only pharmacological treatment during the early stage of disease, had already returned to normal activity, and were complaining of persistent disequilibrium. The diagnostic protocol included clinical examination, posturography, videonystagmography, and rotatory chair and caloric tests that demonstrated a canal paresis of at least 25%. No sign of central lesion emerged by an appropriate clinical and radiological examination.

We randomly assigned patients to two different treatment groups: Group 1 patients received VES, whereas group 2 patients were assigned to rehabilitation via the performance of oculomotor exercises. All patients completed the dizziness handicap inventory short form (DHI) [16] and were tested with static posturography before and after the rehabilitation program.

Dizziness Handicap Inventory Short Form

The DHI is a standardized assessment of functional performance for vertiginous patients [17]. The short form—in which the 25-item, three-level DHI has been reduced to a 13-item, two-level form—was chosen because patients can respond to it more quickly. The retained items explore the domains of eye-head movements, full-body activities, and mood alteration as the DHI scale. Because it has been calculated considering the number of negative (no) responses, the score of the questionnaire is inversely related to the handicap.

Static Posturography

We performed static posturography with patients standing on a stable force plate sensitive to vertical force. The stabilometric platform used for this study was a force plate mounted on three strain-gauge force transducers positioned at the vertices of an equilateral triangle, providing description of body sway in terms of displacement of patients' center of pressure [Standard Vesibology Platform (SVeP) 3.5 system, Amplifon, Milan, Italy]. We recorded all patients in the eyes-opened (EO) and eyes-closed (EC) conditions. For each condition, the following parameters were considered: the length of the oscillations (L), expressed in millimeters and represented by the entire distance covered by the center of pressure of the subject, which is an index of the energy spent; the surface of the body sway (S), expressed in square millimeters and represented by the confidence ellipse containing 90% of the sample position, indicating the precision of the system; and the correlation function between length and surface (LSF), indicating the ratio between the measured length and that statistically expected in normal subjects of the same age group for every surface (again, an expression of the energy spent).

We also tested the patients on foam rubber pads with eyes opened and closed (pad EO, pad EC) so as to have information on the cybernetic ratios existing between the three subsystems: visual (Vis), vestibular (Vest), and somatosensory (Som). We used the following formulas:

- Som: LEO/LEC;
- Vis: LEO/L pad EO; and
- Vest: LEO/L pad EC.

The obtained values were transformed in percentages:

- percentage of somatosensory: Som/Som + Vis + Vest;
- percentage of visual: Vis/Som + Vis + Vest; and
- percentage of vestibular: Vest/Som + Vis + Vest.

The therapeutic protocol used for both groups consisted of daily 40-minute sessions for 10 days with specially trained physical therapists.

For patients in group 1, we placed surface electrodes on the paravertebral nuchal muscles opposite the impaired vestibular side. The stimulus was a biphasic asymmetrical modulated square wave with a pulse width of 100 μsec and a stimulation frequency of 80 Hz. We asked these patients to walk while the electrical stimulator was applied. For group 2 patients, we chose oculomotor exercises among those present, in different rehabilitation protocols [2,18–20]. We invited these patients to stand in an upright orthostatic position without moving the head and to try to maintain balance and to sit only if they felt unable to continue standing. The duration of each exercise was 5 minutes. After the exercises, the patients were invited to walk for the time remaining, as rehabilitation is more effective if the exercises are integrated into such normal activities as walking [21].

In saccadic exercises, we obtained horizontal and vertical visually guided saccades by targets generated by the VisualLab module VN 15/VO25 (Interacoustics, Eden Prairie, MN). In sinusoidal pursuit, patients' eyes had to follow a target moving across the projection screen with constant velocity (20 degrees per second and 40 degrees per second), first horizontally and then vertically. In reading exercises, we asked patients to read paragraphs from a paper being moved by the therapist from one side to another, up and down, forward and backward. For optokinetic stimulation, patients stood in front of a wall on which were displayed luminous stripes of contrasting colors. The stripes moved horizontally and vertically at a velocity of 30 degrees per second in both directions. The patients had to stabilize their gaze without following the stripes and while trying to maintain balance.

Statistical Analysis

We tested for differences between the DHI test values and the performance on posturography using analysis of variance (t-test) in each group before and after treatment. We also performed analysis of variance between the two groups. Values of $p \leq .05$ were considered statistically significant.

RESULTS

After discharge of patients from therapy, verbal reports from all the subjects indicated a reduction of their symptoms. A significant decrease of the amount of dizziness in all subjects was observed by a global increase of DHI score (from 7.2 ± 2.3 to 8.7 ± 2.4; $p = .00019$). The DHI score was significantly improved in both groups ($p < .05$), as shown in Figure 1. The initial DHI score in group 1 was 7.6 ± 2.6, and in group 2 was 6.9 ± 2.0, whereas the final scores were, respectively, 8.7 ± 2.4 ($p = .015$) and 8.7 ± 2.6 ($p = .007$).

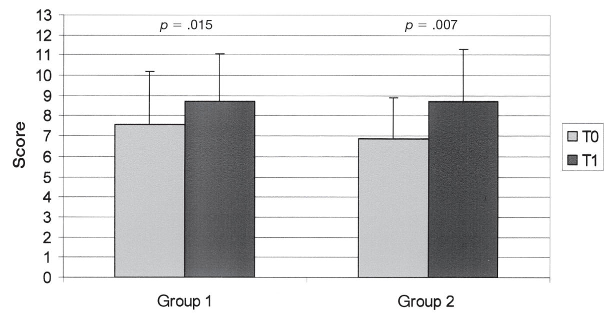

Figure 1. Dizziness Handicap Inventory score before (*T0*) and after (*T1*) treatment in group 1 (vestibular electrical stimulation) and group 2 (oculomotor exercises).

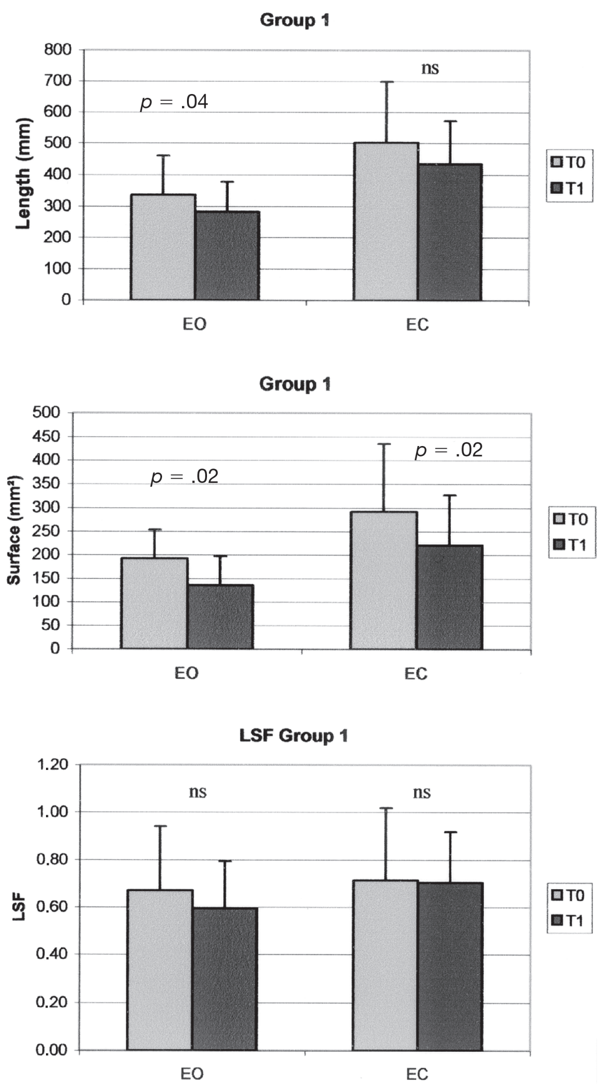

Figure 2. Comparison of Standard Vesibology Platform (Amplifon) length, surface, and length-surface function (*LSF*) values before (*T0*) and after (*T1*) treatment in group 1 (vestibular electrical stimulation). (*EO* = eyes open; *EC* = eyes closed; *ns* = not statistically significant.)

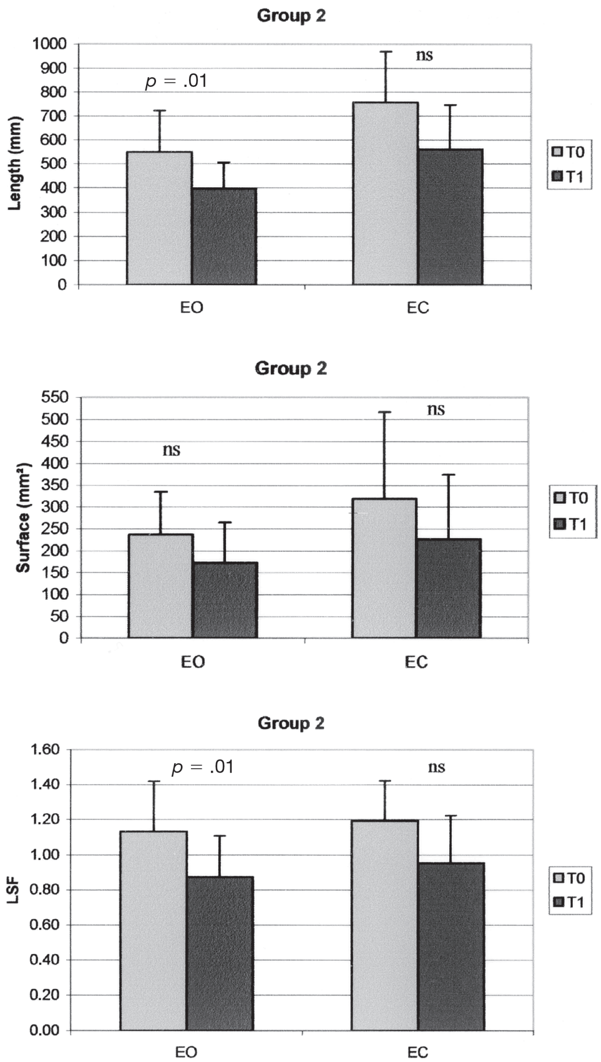

Figure 3. Comparison of Standard Vesibology Platform (Amplifon) length, surface, and length-surface function (*LSF*) values before (*T0*) and after (*T1*) treatment in group 2 (oculomotor exercises). (*EO* = eyes open; *EC* = eyes closed; *ns* = not statistically significant.)

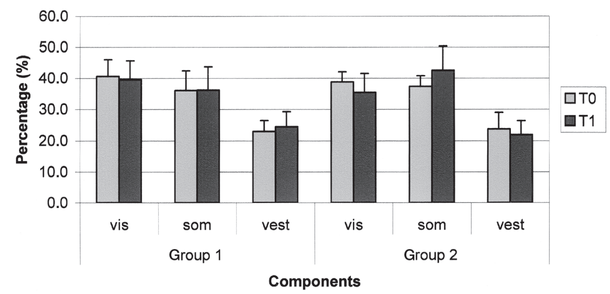

Figure 4. Modifications of equilibrium system components [visual (*vis*), somatosensory (*som*), and vestibular (*vest*)] before and after treatment.

An improvement of DHI score was observed in most patients (71.43% of group 1 and 85.71% of group 2). Only four patients in group 1 and two patients in group 2 reported the same score as was reported before therapy. No patient reported a worsening of DHI score.

At static posturography, group 1 patients showed a reduction of length, surface, and LSF in all the conditions. The reductions of SEO, SEC, and LEO and were statistically significant ($p = .02$, $p = .02$, and $p = .04$, respectively; Fig. 2). Also, patients in group 2 revealed better stability on all parameters, and the reduction of LEO and the EO LSF were statistically significant ($p = .01$ and $p = .01$, respectively; Fig. 3). A comparison of the two groups revealed no statistically significant difference in all posturography parameters and in the DHI score.

Analysis of the components—visual, vestibular, and somatosensory—of the equilibrium system did not show any significant variation (Fig. 4). Nevertheless, an increasing trend of the somatosensory component has been observed in group 2 ($p = .06$).

DISCUSSION AND CONCLUSIONS

Rehabilitation facilitates the recovery of patients with peripheral vestibular lesions as demonstrated by literature since 1940. Most rehabilitative protocols employ exercises that improve either vestibular adaptation or sensory substitution with eye-head coordination and balance retraining exercises in static and dynamic conditions.

Rehabilitation of patients affected by unilateral peripheral vestibular disorders and treated with oculomotor exercises without head movements 1–6 months after the onset of the deficit resulted in both reduced subjective reports of disequilibrium and improved balance. After discharge from therapy consisting of 10 rehabilitative sessions, developed under the guidance of specially trained physical therapists, these patients' DHI scores showed significant improvement, suggesting that patients felt more confident in everyday life.

Also, stability, as evaluated with static posturography, improved significantly after oculomotor rehabilitation in the EO condition as regards both length and the LSF.

The results obtained with the oculomotor exercises are not unlike those derived from the employment of VES. We have used this technique since 1985 in patients with unilateral vestibular diseases, and it has proved to reduce the period of disability after a vestibular deficit.

A comparison of the two rehabilitative methods revealed no significant difference between them (as emerged from a statistical analysis), revealing that both are effective for affected patients. However, the two techniques are supposedly acting on different components of the equilibrium system: Studying the three components—visual, vestibular, and somatosensory—with static posturography added using foam rubber pads, we noticed that in patients treated with VES therapy, the vestibular component had minimally increased after the treatment sessions, whereas in those treated with oculomotor exercises, the somatosensory component was improved at the end of the rehabilitation sessions. The data suggest that oculomotor exercises, stimulating the extraocular muscle proprioceptors, possibly give somatosensory supplementary cues that positively act on postural stability, while VES, through the spinovestibular pathways, directly facilitates the vestibular nuclei contralateral to the stimulated cervical muscles.

Oculomotor exercises employed in most rehabilitative protocols, together with head movements to improve vestibular adaptation, have proved to reduce both the perceived overall impairment and postural sway in patients with recent unilateral vestibular disorders, even though such disorders are not associated with head movements.

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