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Short-term retention effect of rehabilitation using head position-based electrotactile feedback to the tongue: Influence of vestibular loss and old-age

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ABSTRACT

Our objective was to evaluate whether the severity of vestibular loss and old-age (>65) affect a patient's ability to benefit from training using head-position based, tongue-placed electrotactile feedback. Seventy-one chronic dizzy patients, who had reached a plateau with their conventional rehabilitation, followed six 1-h training sessions during 4 consecutive days (once on days 1 and 4, twice on days 2 and 3). They presented bilateral vestibular areflexia (BVA), bilateral vestibular losses (BVL), unilateral vestibular areflexia or unilateral vestibular losses and were divided into two age-subgroups (≤65 and >65). Posturographic assessments were performed without the device, 4 h before and after the training. Patients were tested with eyes opened and eyes closed (EC) on static and dynamic (passively tilting) platforms. The studied posturographic scores improved significantly, especially under test conditions restricting either visual or somatosensory input. This 4-h retention effect was greater in older compared to younger patients and was proportional to the degree of vestibular loss, patients with increased vestibular losses showing greater improvements. In bilateral patients, who constantly fell under dynamic-EC condition at the baseline, the therapy effect was expressed by disappearance of falls in BVL and significant prolongation in time-to-fall in BVA subgroups.

Globally, our data showed that short training with head-position based, tongue-placed electrotactile biofeedback improves balance in chronic vestibulopathic patients some 16.74% beyond that achieved with standard balance physiotherapy. Further studies with longer use of this biofeedback are needed to investigate whether this approach could have long-lasting retention effect on balance and quality of life.

1. Introduction

Supplying individuals with artificial sensory information on body position, orientation and displacements has been shown to improve balance performances [1–7]. Based on these findings many biofeedback systems have been developed employing either visual [1], auditory [2–4] or tactile [4–7] input. The BrainPort balance device (Wicab Inc., Middleton, WI, USA) is one of these systems [5,11]. It uses the tongue as an alternative sensory channel to convey afferent information relating to a patient's head position in real time. It is well known that head displacements are normally detected by the vestibular system [8]. Its role in head and body stabilization and orientation is well documented and explains gait and posture impairments in vestibular patients [9]. The BrainPort balance device was developed with the objective of enhancing postural-kinetic performances by substituting vestibular cues while freeing up the visual and auditory inputs normally involved in balance control and spatial orientation.

Previous studies demonstrated the ability of the CNS to efficiently integrate this head position-based, tongue-placed biofeedback for head stabilizing [5] and controlling upright posture [10] in vestibular-defective patients. Moreover, it was shown that stability improvements continue after disconnection of the device and this residual effect is linearly related to the time the device is used [5]. A specific training program was then proposed using the BrainPort balance device as a rehabilitation tool [11]. Its retention effect was observed in patients with moderate to severe balance dysfunction resulting from various sensorimotor impairments [5,11–13]. However, the extent to which the severity of vestibular loss and old-age (>65) interfere with the patient's potential to benefit from this therapy is still unknown. In the present study, the short-term retention effect of BrainPort-therapy was assessed in chronic dizzy patients with different degrees of vestibular losses, ranging from unilateral vestibular deficit to

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bilateral vestibular areflexia. Our objective was to determine whether the above mentioned factors, affecting the neuronal plasticity, influence therapy outcome.

2. Materials and methods

2.1. Subjects

After approval of the institutional review board, the files of 71 consecutive patients (37 women and 34 men) who underwent BrainPort-therapy were submitted for a retrospective review. Patients gave informed consent as required by the Helsinki declaration (1964). Their age ranged from 38 to 84 (mean 65.11 ± 11.99). 35 patients were 65 or under while 36 patients were over 65, thus forming two age-subgroups ($\leq$65 and >65). The studied sample was divided into the following four subgroups: bilateral vestibular areflexia (BVA), bilateral vestibular losses (BVL), unilateral vestibular areflexia (UVA) and unilateral vestibular losses (UVL). This classification was based on the bythermal-caloric and 0.25 Hz rotating-chair tests [14] performed by videonystagmography (VNG-Ulmer, Synapsys, Marseille, France). Demographic and vestibular test data are outlined in Table 1 for each vestibular-subgroup (Table 1).

All the patients presented balance disturbances for at least 1 year. They benefited from appropriate medical and/or surgical treatments, counseling, and changes in their medical prescriptions aiming to minimize the effect of polymedication on balance control. In addition, all the patients benefited from 20 to 50 sessions (mean 35.54 ± 6.98) of conventional rehabilitation. This traditional approach relieved the original symptoms. However, patients reported persistent dizziness and moderate to severe handicap as evaluated by the Dizziness Handicap Inventory (DHI) [15] and showed abnormal posturographic scores (SPS platform, Synapsys, Marseille, France) [16].

The studied sample does not include patients with acute vestibulopathies, severe neurological or psychiatric conditions, nor patients with contraindication for use of the BrainPort balance device (communicable diseases, open mouth or tongue sores, neuropathies of the tongue).

2.2. BrainPort balance device

The BrainPort balance device is a portable system including an intraoral device (IOD) placed on the tongue and a controller equipped with a computer. The IOD contains an electrotactile array and a 3-axis, digital output accelerometer detecting both anterior–posterior (AP) and medial–lateral (ML) head displacements. The system microprocessor acquires acceleration information, estimates head pitch and roll angles and consequently activates specific 2×2 arrays within a larger 10×10 array regrouping 100 gold-plated electrodes. The activated electrodes deliver the electrical stimulation (bursts of three 25 μs-wide pulses at 200 Hz repeated at 50 Hz) to the dorsum of the tongue. Mapping the data to the array causes "binning" of the output signal into 2.8° increments to individual tactor rows, to a maximum range of ±14° in each direction. This allows a subject to detect the typical postural sway occurring in semi-static position [11]. When the head position temporarily exceeds the display's range limit, the stimuli pattern remains at the outer edge allowing the subject to not lose the position information. Therefore, users continuously perceive head position and displacements through "tingling" stimuli mapped onto the tongue.

The goal of training is to make corrective postural adjustments in order to center the stimulus on the tongue thus achieving better head stabilization and appropriate balance.

2.3. Training procedure

Two 1-h sessions, separated by 4 h, were conducted daily during 4 consecutive days. The first and last visits were used only for balance assessment. During the other six visits (once on days 1 and 4, twice on days 2 and 3) each patient followed an individualized training program including five 5-min and one 20-min trials separated by rest periods. During training, patients used the device while performing balance exercises. These were done eyes closed, in standard then sensitized Romberg positions on firm then various foam surfaces and were challenged by imposing dynamic postural-kinetic tasks depending on their ability. Patients progressed to the next level when they were able to perform a 5-min trial without needing assistance. For 20-min trials, the postural tasks were challenging but not tiring. A physiotherapist conducted this individualized program based on his own clinical evaluation.

2.4. Posturographic assessment

The patient's balance was assessed using the SPS posturography system allowing us to record AP and ML center of pressure (CoP) sway separately. A passively tilting platform, imposing a self-regulated balance task, was used to test dynamic balance [17]. It was placed on the static SPS platform with its axis oriented first in the pitch (DYNAP) then in the roll planes (DYNML). The patient's sway caused the platform to rotate, thus amplifying AP or ML sway selectively, requiring postural reactions in the plane of provoked postural disturbances.

Eyes opened and eyes closed trials were carried out on the static (ST-EO and ST-EC), DYNAP (DYNAP-EO and DYNAP-EC) then DYNML (DYNML-EO and DYNML-EC) support surfaces. Patients were instructed to maintain their balance without moving or standing stiffly. Two trials of 20 s were performed under each test condition without the device, 4 h before the first and 4 h after the last training sessions.

Before therapy, the limits of stability (LoS) were additionally defined for each patient as their maximum possible straight body

Table 1
Age and sex repartition and data from videonystagmography tests in subgroups of patients with bilateral vestibular areflexia (BVA), bilateral vestibular losses (BVL), unilateral vestibular areflexia (UVA) and unilateral vestibular losses (UVL).

Patients subgroups	Number total (men; women)	Age mean ± standard deviation (range)	Videonystagmography data	
			Responses to bythermal caloric test	VOR gain to rotary chair test
BVA	17[a] (12; 5)	59.35 ± 8.34 (49–75)	Bilaterally absent	$\leq$0.05
BVL	11 (4; 7)	74.82 ± 10.74 (48–83)	Bilaterally reduced	<0.4
UVA	20[b] (5; 15)	59.55 ± 14.49 (38–83)	Unilaterally absent, 100% asymmetry	$\geq$0.4
UVL	23 (13; 10)	65.17 ± 12.82 (39–84)	Unilaterally reduced, 34–92% asymmetry	$\geq$0.4

No patients presented cerebellopontine angle tumors outside the internal auditory meatus.
[a] 3 patients had a bilateral vestibular neurectomy (VN) for disabling Menier's disease (MD).
[b] 14 patients had a unilateral VN for disabling MD ($n = 11$) and vestibular schwannoma ($n = 3$).