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Vestibular rehabilitation by auditory feedback in otolith disorders

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Abstract

Rehabilitation strategies have been applied successfully over the last few decades to initiate central compensation of the tonus imbalance and to facilitate substitution in different types of peripheral vestibular dysfunction. However, these vestibular rehabilitation strategies are often not successful in patients with isolated otolith disorders. The aim of the present study was therefore to evaluate a specific rehabilitation strategy for patients with an isolated otolith disorder by using an auditory feedback system.

Thirteen patients, which suffered from different types of otolith disorders, but no other vestibular pathology and 13 normal controls were included in this study.

Vestibular rehabilitation exercises were performed daily over a 2-week period (weekends excluded). During all exercises the patients of the test group ($n = 13$) obtained an acoustic feedback signal when their trunk angle velocity exceeded a preset level while the patients of the control group ($n = 13$) performed the same exercises without auditory feedback.

The most effective exercise in the test group was ‘‘walking eight tandem steps on a foam support surface’’. Approximately 85% of the patients showed a significant decrease of trunk sway in this condition. In contrast to these results, patients of the control group showed no significant improvement of postural control after the training.

The results indicate that an auditory feedback rehabilitation program with exercises related to the specific neurotological disease could significantly improve the postural control in patients with otolith disorders.

Keywords: Otolith disorder; Vestibular rehabilitation; Minor head trauma; Auditory feedback

1. Introduction

Vestibular rehabilitation strategies have been applied successfully over the last few decades to initiate central compensation of the tonus imbalance and to facilitate substitution [1] in different types of peripheral vestibular dysfunction [2]. Various exercise programs (home or supervised) have been described, including physical training, Cawthorne–Cooksey interventions, alternative strategies – such as Tai Chi – simulator-based training with virtual reality, etc. [3–9]. However, these vestibular rehabilitation strategies are not successful in patients with isolated otolith disorders [10]. These saccular or utricular deficits (uni- or bilateral) are frequent sequelae of blunt head trauma (minor head injury), which can be diagnosed by specific testing [11–13]. The patients complain of ‘‘walking on pillows’’, ‘‘unsteadiness’’ in the dark or at reduced visual surround control and are frequently unable to drive a car or work for a longer period of time at a personal computer [14].

Training procedures, which use a sensory feedback, are possibly more suited for the vestibular rehabilitation of patients with these neurotological symptoms. A significant improvement of postural control in patients with semicircular canal (SCC) function loss was earlier reported with a vibrotactile feedback system [15,16]. This method could be crucial for some patients because vibration can lead to an illusion of movement by driving proprioceptive afferents [17,18]. Current studies reported a significant reduction of trunk sway during auditory feedback in patients with bilateral loss of SCC function [19,20].

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The aim of the present study was to apply the recently developed auditory feedback device (APFD) in patients with otolith disorders as a new rehabilitative approach.

2. Methods

2.1. Patients' characteristics

Thirteen patients (seven females −41.4 ± 10.3 years; six males −51.3 ± 14.3 years) were included in the auditory feedback-training group. Thirteen additional patients (age and gender matched) were in the control group (training without auditory feedback). All patients suffered from different types of otolith disorders (saccular, utricular, combined dysfunction), but no other vestibular pathology. The otolith disorders were diagnosed by recording the otolith-ocular responses during eccentric rotation [11] to test utricular function. The saccular function was tested by acoustically elicited vestibular evoked myogenic potentials (VEMP) [12,21,22]. All patients had undergone a minor head trauma [23]. MRI/CT scans of the neurocranium, the skull base and the craniocervical junction show no evident pathology (e.g. fractures, haematomas) and no intracranial pathology was found. The patients had clinically quickly recovered, except that they complained of "dizziness" ("unsteadiness", "slipping away", "tumbling") at a later follow-up (on average 3 months after the initial trauma), which led to their referral. The patients had no other sensory deficits (e.g. auditory symptoms, blurred vision, anosmia) or other vestibular pathology (video-oculographic testing).

2.2. Vestibular rehabilitation exercises

Vestibular rehabilitation exercises were performed daily over a 2-week period (weekends excluded). The exercises selected were the most sensitive ones for otolith disorders when testing the patients with the standard balance deficit test (SBDT) as demonstrated earlier [12]. The exercises included (in the following order):

- standing with eyes closed,
- standing on a foam support surface with eyes open,
- standing on a foam support surface with eyes closed,
- walking eight tandem steps (one feet in front of the other) on a foam support surface.

These exercises were performed by the auditory feedback-training group as well as by the control group (no auditory feedback provided). Each of the exercises was repeated 3× in the daily sessions.

The auditory feedback-training group used the auditory feedback training option included in the Sway-Star^{TM} system. The system was extensively described in previous publications [24]. In brief, the device contains two angular velocity transducers, mounted on an elastic belt, which is positioned on the patient's lower trunk. The transducers are oriented in roll and pitch planes. A software programme records and analyses the velocity and angle of trunk movements and calculates the related auditory feedback. Auditory biofeedback was delivered via four loudspeakers placed left, right, in front and back of the patient (5 m × 4 m test environment).

The trunk angle velocity was most indicative of any specific type of otolith disorder as demonstrated earlier [13]. Therefore this parameter was used as the reference point for the acoustic feedback signal, i.e. angle velocity of trunk sway greater than the preset levels caused a tone to be emitted from that loudspeaker towards the patient had moved. The tone volume was increased linearly with increasing angular velocity from 60 dB to 95 dB SPL. The angular velocity thresholds were estimated every day for each patient individually before the onset of exercises.

Evaluation of the effects of the vestibular rehabilitation exercises:

Table 1
Number of patients with otolith disorders which showed a significant improvement of postural control after auditory feedback training (10 sessions, four tasks)

Task	Parameter with most frequent significant changes	Patients with significant improvement	Mean improvement in (%)
Standing EC	Total angle area	7	233.3
Standing on foam EO	Total velocity area	7	150.2
Standing on foam EC	Total velocity area	10	563.9
Walking tandem steps on foam	Total velocity area	11	131.1

(n = 13).

Table 2
Characterization of patients with otolith disorders which showed a significant or non-significant improvement of postural control after the auditory feedback training (10 sessions, four tasks)

Task	Significant improvement				Non-significant improvement			
	Gender M/F	Age in years	Change of DHI-value	Change of DGI-value	Gender M/F	Age in years	Change of DHI-value	Change of DGI-value
Standing EC	5/2	51.4 ± 10.3	−4.1 ± 4.9	1.1 ± 2.8	1/5	37.8 ± 8.7*	−1.3 ± 2.1	0.8 ± 1.8
Standing on foam EO	4/3	48.2 ± 14.2	−4.5 ± 5.2	1.2 ± 1.9	2/4	42.5 ± 7.2	−2.6 ± 3.1	0.9 ± 2.2
Standing on foam EC	6/4	47.2 ± 12.5	−4.8 ± 7.5	1.2 ± 3.1	0/3	41.1 ± 7.1	−0.8 ± 1.2	0.5 ± 1.0
Walking tandem steps on foam	6/5	46.3 ± 11.9	−4.5 ± 6.9	1.5 ± 3.2	0/2	41.2 ± 9.9	−0.6 ± 1.0	0.6 ± 1.1

(n = 13). Asterisks indicate significant differences ($p < 0.05$). Changes in dizziness handicap inventory (DHI) and dynamic gait index (DGI) are shown as the difference between the mean values before and after the rehabilitation period.