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Efficacy of a Vibrotactile Neurofeedback Training in Stance and Gait Conditions for the Treatment of Balance Deficits: A Double-Blind, Placebo-Controlled Multicenter Study

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Objective: Vestibular rehabilitation strategies mostly require a long-lasting training in stance conditions, which is finally not always successful. The individualized training in everyday-life conditions with an intuitive tactile neurofeedback stimulus seems to be a more promising approach. Hence, the present study was aimed at investigating the efficacy of a new vibrotactile neurofeedback system for vestibular rehabilitation.
Study Design: Double-blinded trial.
Patients: One hundred five patients who experience one of the following balance disorders for more than 12 months were included in the study: canal paresis, otolith disorder, removal of an acoustic neuroma, microvascular compression syndrome, Parkinson's disease, and presbyvertigo.
Interventions: Vibrotactile neurofeedback training was performed daily (15 min) over 2 weeks with the Vertiguard system in those 6 tasks of the Standard Balance Deficit Test with the most prominent deviations from the normative values.
Main Outcome Measures: Trunk and ankle sway, dizziness handicap inventory, and vestibular symptom score were measured in the verum and placebo group before the training, on the last training day and 3 months later.
Results: A significant reduction in trunk and ankle sway as well as in the subjective symptom scores were observed in the verum group. Such an effect could not be found in any of the outcome parameters of the placebo group.
Conclusion: The vibrotactile neurofeedback training applied in the present study is a highly efficient method for the reduction of body sway in different balance disorders. Because the rehabilitation program is easy to perform, not exhausting, and time saving, elderly patients and those with serious, long-lasting balance problems also can participate successfully. **Key Words:** Neurofeedback—Postural control—Vestibular rehabilitation—Vibrotactile.
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Numerous diseases are accompanied by balance deficits, which are frequently characterized by an increase in body sway and a higher risk to fall. Different strategies in the conservative management of those balance deficits have been applied successfully over the last few decades to improve central compensation of the tonus imbalance within the vestibular system and to facilitate substitution (1) in different types of peripheral or central vestibular disorders (2,3). Various exercise programs (home or supervised) have been described, including physical training (4), Cawthorne-Cooksey interventions (5), and alternative strategies—such as Tai Chi (6).

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However, these vestibular rehabilitation strategies mostly require a long-lasting, intensive training approach (i.e., over several weeks or even months) which is finally not always successful. Current studies have shown that rehabilitation strategies including a sensory feedback signal could be much more effective. The first feedback applications consisted of stance tasks with visual feedback (3,7,8), galvanic feedback (9,10), or vibrotactile feedback (11,12). Because patients tend to fall mostly in dynamic (i.e., movement) conditions, those stance tasks in balance rehabilitation should be accompanied by gait (or dynamic) tasks including daily-life situations. Earlier studies showed a high effectiveness of a free-field auditory neurofeedback training to reduce the body sway in patients with different peripheral vestibular disorders (13–15). This auditory neurofeedback application, however, is limited to the laboratory situation and those patients with good hearing (which is frequently not the case in the elderly or patients with a vestibular disorder). Therefore, an intuitive tactile neurofeedback stimulus could be superior for encoding of the individual sway information during the training of everyday-life conditions.

Hence, the present study was aimed at investigating the efficacy of a newly developed method for vestibular rehabilitation with a vibrotactile neurofeedback system.

MATERIALS AND METHODS

Patients' Characteristics

Patients which chronically experienced dizziness (longer than 12 mo) were recruited within 17 months from neuro-otologic or neurologic clinics.

The inclusion criteria to participate in the neurofeedback training program was a pathologic body sway (measured at the hip in pitch and roll direction) compared with normal age- and sex-related controls as recorded by the diagnostic, mobile posturography device Vertiguard-D (Vesticure GmbH, Germany). The pathologic sway should be found in at least one of the test conditions of the Standard Balance Deficit Test (SBDT) (15) or the Geriatric Standard Balance Deficit Test (gSBDT) (manual Vertiguard, Vesticure GmbH).

The SBDT contained the following 14 tasks: standing on 2 legs with eyes open/closed, standing on 1 leg with eyes open/closed, 8 tandem steps (1 foot in front of the other) with eyes open, standing with 2 legs on a foam support surface (height, 10 cm; density, 25 kg/m^3) with eyes open/closed, standing on 1 leg on a foam support surface, 8 tandem steps on a foam support surface, walking 3 m while rotating the head, walking 3 m while vertically pitching the head in rhythm, walking 3 m forward with eyes open/closed, and walking over 4 barriers (height of 26 cm with an interbarrier distance of 1 m).

The following tasks were skipped in the gSBDT (for patients older than 59 yr): standing on 1 leg with eyes closed and standing on 1 leg on a foam support surface.

The tasks ''stand up'' and ''sit down'' were added as last conditions to the gSBDT.

The recording time was 20 seconds for all stance tasks and as long as required for gait tasks (mostly <20 s).

Exclusion criteria for the study were as follows: the use of drugs, which actively influence the vestibular system (e.g., cinnarizine, dimenhydrinate, betahistidine); sensory deficits exceeding age-related values (e.g., auditory symptoms, blurred vision, anosmia); a combination of different types of vestibular disorders in 1 patient (e.g., canal paresis and otolith disorder) because 1 important aim of the present study was to investigate a possible correlation between the efficacy of the training and a specific vestibular disorder; an acute vestibular disorder (due to World Health Organization definition); and all included patients received no other treatment (whether medical, surgical, or rehabilitative) for their balance disorder during the study period.

Of the 132 patients who experienced dizziness or instability, 27 were excluded from the study. Seven of them showed a combination of different types of vestibular disorders; 4 had sensory deficits, which exceeded the normal age-related values (auditory symptoms); and 16 patients showed no pathologic body sway within the SBDT. In total, 105 patients were included in this study. The sample contained patients with 6 different peripheral or central balance disorders, including the following (for details, see Table 1): unilateral canal paresis (semicircular canal paresis [SCC]); otolith disorder (O), that is, unilateral or bilateral loss of sacculo-utricular function; patients after removal of an acoustic neuroma (AN) with resection of the vestibular nerve; micro(neuro) vascular compression syndrome (MVCS) of the VIIIth cranial nerve; Parkinson's disease (PD); and presbyvertigo (P), that is, patients older than 59 years with no specific vestibular deficit but an increase in body sway as result of this complex disorder.

Patients with an otolith disorder showed a combined sacculo-utricular dysfunction. All the vestibular tests were applied to all patients to exclude an overlapping of group-specific pathologies. Pathologic findings in the vestibular testing of the same side as affected by an AN or a micro(neuro) vascular compression were related to the disorder of the VIIIth nerve function. The vestibular test battery contained the following procedures: caloric testing (pathologic results: side differences of more than 15% [slow phase velocity]); cervical vestibular evoked myogenic potentials (pathologic results: absence of N1/P1 even if the required tonic muscle activity was achieved); and subjective haptic vertical (pathologic results: side asymmetry or difference to the vertical of more than 10 degrees).

TABLE 1. *Characterization of treatment subgroups and classification criteria*

Subgroup	Age	n	Female	Male	Classification criteria
Semicircular canal function loss	60.2 ± 13.6	25	10	15	Pathologic results during caloric irrigation
Otolith disorder	54.6 ± 13.8	21	10	11	Pathologic vestibular evoked myogenic potentials or subjective haptic vertical
Acoustic neuroma removal	60.2 ± 10.1	10	4	6	Surgical removal of an acoustic neuroma
Microvascular compression syndrome	52.0 ± 10.8	12	6	6	Radiographic defined 8. Nerve-anterior inferior cebellar artery contact
Parkinson's disease	68.1 ± 9.1	10	2	8	Idiopathic type
Presbyvertigo	73.4 ± 6.0	13	6	7	Dizzy elderly patients (>59 yr) without a vestibular disease

After calculating the minimal sample size for the control (placebo) group by using the software G*Power 3.1.2 (University Kiel, Germany) (16) with an effect size of 0.9, $p = 0.05$, and a statistical power of 0.8, 14 patients were randomly selected from the initial study sample of 105 patients under consideration of the initial distribution of balance disorders and sex. Six female subjects (64.0 ± 9.6 yr) and 8 male subjects (58.8 ± 8.5 yr) were included in the control group with the following distribution of balance disorders: SCC, 28.6%; O, 21.4%; AN, 14.3%; MVCS, 14.3%; PD, 7.1%; and P, 14.3%.

All other patients were included in the treatment group. This group contained 91 patients (39 female subjects—59.1 ± 14.1 yr; 52 male subjects—61.7 ± 12.7 yr). The distribution of balance disorders and sex was similar to that of the control group. Table 1 shows the details of the treatment subgroups and the classification criteria.

Vestibular Rehabilitation Training

The training was performed using the Vertiguard training device (Vesticure GmbH). It contains a battery-driven main unit (120 × 76 × 32 mm, 190 g) which is fixed on a belt at the center of body mass (hip) and 1 vibration stimulator on the front, back, left, and right side, respectively (Fig. 1). The vibration stimulators are mounted on the same belt as the main unit. They are adjustable by sliding them over the belt into the correct position of the individual patient. The main unit continuously records the Coriolis force during body movements in pitch and roll by inbuilt gyroscopes and compares those values with individually preset thresholds for the stimulator activation in the specific direction. Preset thresholds were task specific. They were determined for the individual patient based on the maximum age- and sex-related normative sway in the specific SBDT condition and sway direction. The thresholds were stored for each training task in the main unit. Training tasks were selected automatically by analyzing the results of the SBDT or gSBDT. Only those 6 tasks with the most prominent deviations from the normative values were included in the training program. The number of training tasks was limited by the device capacity. This is related to the assumption that almost all patients show a pathologic sway in not more than 6 conditions of the SBDT. The patient was able to switch between the tasks by pressing a button on the main unit. To prevent the selection of wrong thresholds for the performed task, the chosen task was shown together with the patient's name in the display of the main unit. No vibrotactile feedback stimulus was delivered via the stimulators if the patients' sway were below the preset thresholds. In contrast to this, if the body sway exceeded the thresholds, the perceived vibration was increased with the amplitude of body sway. The patients were instructed daily by a nurse to adjust the vibratory stimulation step by step (within a scale of 10 steps) at the beginning of each selected training task by pressing the sensitivity buttons (up/down) on the main unit. During this procedure, the individual preset thresholds were similarly decreased for all sway directions of the specific training condition until the patient perceived a vibration during performing the training task.

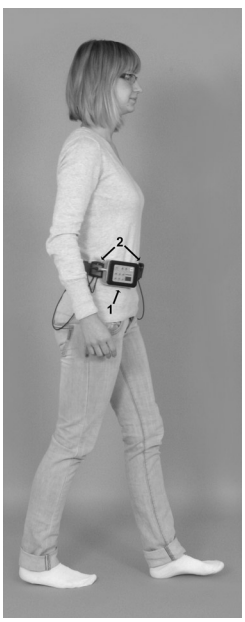

FIG. 1. Application of the vibrotactile neurofeedback system Vertiguard for the treatment of balance disorders. The system with the main unit (1) and the vibration stimulators (2) is fixed on a belt at the center of body mass. Only 2 of the 4 vibration stimulators are visible in the picture.

Vestibular rehabilitation exercises were performed daily over a 2-week period with 10 days of exercising (weekends excluded). Each session contained 5 repetitions of the selected tasks. The time limit for 1 repetition was 20 seconds for all stance tasks and as long as needed for gait tasks (similar to the recording time of the SBDT/gSBDT). The total daily training time was approximately 15 to 20 minutes.

Patients of the control group performed the similar protocol with a sham device (emitting randomly assigned signals to the vibrators). The patients as well as the supervisor did not know the group classification (double-blinded study design).

Evaluation of the Effects of the Vestibular Rehabilitation

Trunk sway of the patients was measured in pitch and roll for each exercise task (without feedback) before and after the training by means of the Vertiguard D system (Vesticure GmbH). The results were averaged across all tasks.

The composite score of the sensory organization test (SOT) of the BalanceMaster (Nicolet Biomedical, Clackamas, OR, USA) ankle-sway referenced system (platform), the dizziness handicap inventory (DHI) (17), and the vestibular symptom score (VSS) (18) were obtained before the training, on the last training day, and 3 months later.

Objective measures of trunk sway (pitch and roll) and ankle sway (SOT composite score) were used as primary end points. The SOT composite score is scored between zero (fall) and 100 (maximum stability). The results of questionnaires (DHI and VSS) were classified as secondary end points. Lowering of DHI or VSS scores indicate a decline of handicaps or symptoms. Primary and secondary end points were statistically compared in the treatment group (also for all subgroups) and placebo group before and after the rehabilitation period by the *t* test for dependent samples or the Wilcoxon's test (depending on data distribution). The similar tests were used for the comparison between the results of all investigated parameters before the training and after the follow-up (SPSS 11.0). A Bonferroni alpha correction was applied for multiple comparisons. In the case of missing values, the patient was excluded from the analysis of the related parameters. Data were tested for a normal distribution by the Kolmogoroff-Smirnoff test.

The statistical power and effect size was determined by post hoc calculations for each comparison with the software G*Power 3.1.2 (University Kiel, Germany) (16). Statistical power estimates

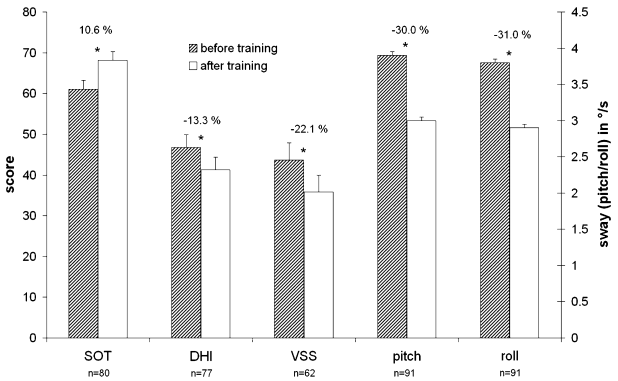

FIG. 2. Mean values (± standard error of the mean [SEM]) and percentage changes of the SOT (BalanceMaster/Neurocom), the DHI, the VSS, and the body sway (pitch/roll) before and after a vibrotactile neurofeedback training in the treatment group. Numbers given below represent the number of patients included in the measurement. *Asterisks* indicate significant differences.

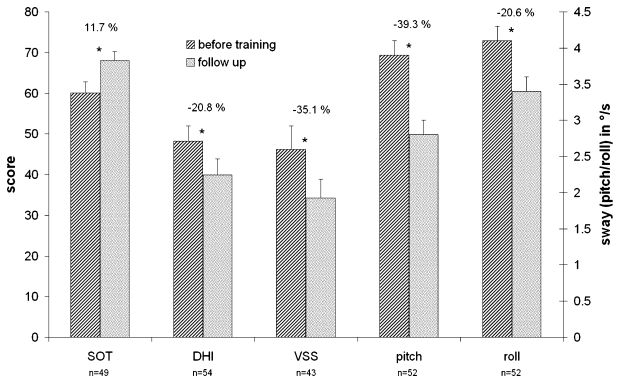

FIG. 3. Mean values (±SEM) and percentage changes of the SOT (BalanceMaster/Neurocom), the DHI, the VSS, and the body sway (pitch/roll) before a vibrotactile neurofeedback training and 3 months after the training in the treatment group. Numbers given below represent the number of patients included in the measurement. *Asterisks* indicate significant differences.

the probability of detecting a change, given that a change has occurred and effect size emphasizes the size of the change rather than confounding this with sample size. Both are very useful for the practical evaluation of the p value. The highest (best) value for the statistical power is 1. A sufficient effect size is higher than 0.5. The level of significance in all tests applied was $p < 0.05$.

A review board approved the study protocol. The patients gave their written, informed consent to participate in the study.

This study was carried out in accordance with the requirements of DIN EN ISO 14155-1/2.

RESULTS

Total Treatment and Placebo Group

The study was conducted from August 2009 until December 2010. No statistically significant differences could be determined with respect to age and sex between the treatment and placebo group (treatment/placebo: sex 42.8%/42.9% female, 57.2%/57.1% male; age 60.6 ± 13.3/61.3 ± 9.2).

The results of the primary end points before and immediately after the training were statistically significantly different in the treatment group (Fig. 2). The trunk sway decreased in the pitch direction by 30% (power, 1.00; effect size, 0.81) and 31% in roll direction (power, 0.99; effect size, 0.65).

The composite score of the SOT increased significantly (increase of stability) by 10.6% on average (power, 0.99; effect size, 0.64). This increase was mainly related to an improved performance in Tasks 5 and 6 of the SOT (Table 2).

The data of the secondary end points, the scores of the questionnaires DHI and VSS, were significantly reduced (reduced symptoms) after the training (power, 0.99; effect size, 0.48; and power, 0.99; effect size, 0.63, respectively). Significant differences also were found for all investigated parameters at the follow-up over time (Fig. 3), although only 60% of the initial patients attended the follow-up measures.

No statistically significant differences could be observed for trunk sway measures or in the SOT immediately after the training of the placebo group (Fig. 4) even if the SOT tasks were separately analyzed (Table 2). The same holds true for the secondary end points, the DHI, and the VSS (Fig. 4).

Treatment Subgroups

Analysis of Pathologic Conditions

The percentage of patients with a pathologic sway is shown for each condition of the SBDT in Figure 5. In all subgroups, the most frequent training tasks were on a foam support surface. There seems to be a trend for a lower occurrence of pathologic sway in walking conditions for patients with otolith disorders. Patients of the PD, MVCS, and P subgroup showed a pathologic sway also frequently in walking tasks.

TABLE 2. *Results of the Sensory Organization Test on the BalanceMaster (Neurocom) for tasks 1 to 4 and 5 to 6*

	Treatment group			Placebo group		
Task	Before training	After training	p value	Before training	After training	p value
SOT 1–4	80.9 ± 1.6	82.5 ± 1.5	0.074	74.5 ± 7.0	78.7 ± 5.4	0.103
SOT 5–6	40.9 ± 3.2	54.0 ± 3.1	0.001*	47.2 ± 11.4	54.0 ± 8.4	0.475

Data shown are for the treatment and placebo groups. Asterisks indicate significant differences between values before and after the training.

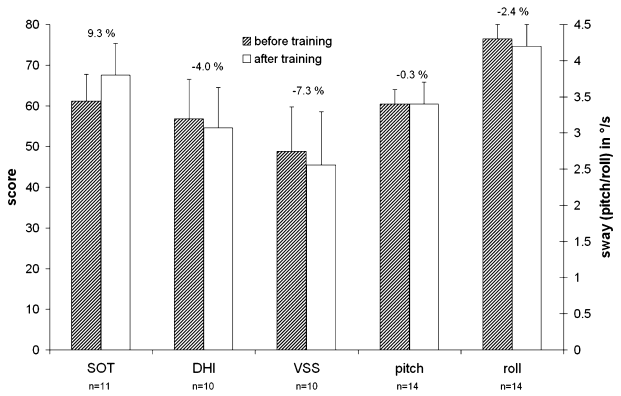

FIG. 4. Mean values (±SEM) and percentage changes of the SOT (BalanceMaster/Neurocom), the DHI, the VSS, and the body sway (pitch/roll) before and after a vibrotactile neurofeedback training in the placebo group. Numbers given below represent the number of patients included in the measurement. *Asterisks* indicate significant differences.

Effect of Training on Trunk Sway

The trunk sway in pitch direction was decreased significantly (Fig. 6) in all subgroups (SCC: power, 0.98; effect size, 0.77; O: power, 0.83; effect size, 0.59; AN: power, 0.76; effect size, 0.81; MVCS: power, 0.58; effect size, 0.63; P: power, 0.98; effect size, 1.13; PD: power, 0.98; effect size, 1.28). Figure 7 shows the mean group values of the trunk sway in roll direction before and after the training. The trunk sway in roll direction was significantly decreased after the training in all subgroups with the exception of the MVCS patients (SCC: power, 0.91; effect size, 0.61; O: power, 0.63; effect size, 0.45; AN: power, 0.81; effect size, 0.86; P: power, 0.75; effect size, 0.68; and PD: power, 0.99; effect size, 1.38).

Effect of Training on SOT Composite Score

A significant increase of the SOT composite score (Conditions 1–6) could be observed in the SCC (power, 0.95; effect size, 0.73), O (power, 0.7; effect size, 0.55), P (power, 0.84; effect size, 0.77), and PD (power, 0.84; effect size, 0.91) subgroups (Fig. 8). Patients of the AN and MVCS subgroups increased their stability on the platform not statistically significantly on average (Fig. 8).

Effect of Training on DHI Score

The DHI score, as one of the secondary end points, showed significant differences only in the SCC and PD groups (Fig. 9) with a statistical power of 0.7 (effect size, 0.55) and 0.95 (effect size, 1.15), respectively.

Only a trend for a reduced DHI score was visible for the AN, MVCS, and P group.

Effect of Training on VSS Score

The other secondary end point, the VSS scores, was significantly reduced in the SCC and O groups (Fig. 10). The statistical power was 0.94 (effect size, 0.9) for the SCC and 0.93 (effect size, 0.84) for the O group. A trend for a reduction of the mean VSS score was observed for all other investigated subgroups. Patients of the PD group were not asked to fill in the VSS questionnaire.

DISCUSSION

The present results indicate that a specific vibrotactile neurofeedback rehabilitation program, which is "tailored" to meet the needs of the individual balance deficit, can significantly improve the postural control in stance and gait situations. This could be demonstrated by the significant reduction of body sway in pitch and roll directions during everyday-life test conditions and the significant increase of stability (SOT composite score) in different sensorimotor stance conditions (force plate measurements). The performance on the SOT improved especially in the more vestibular related Tasks 5 and 6. This finding indicates the specific effect of the training on vestibular rehabilitation.

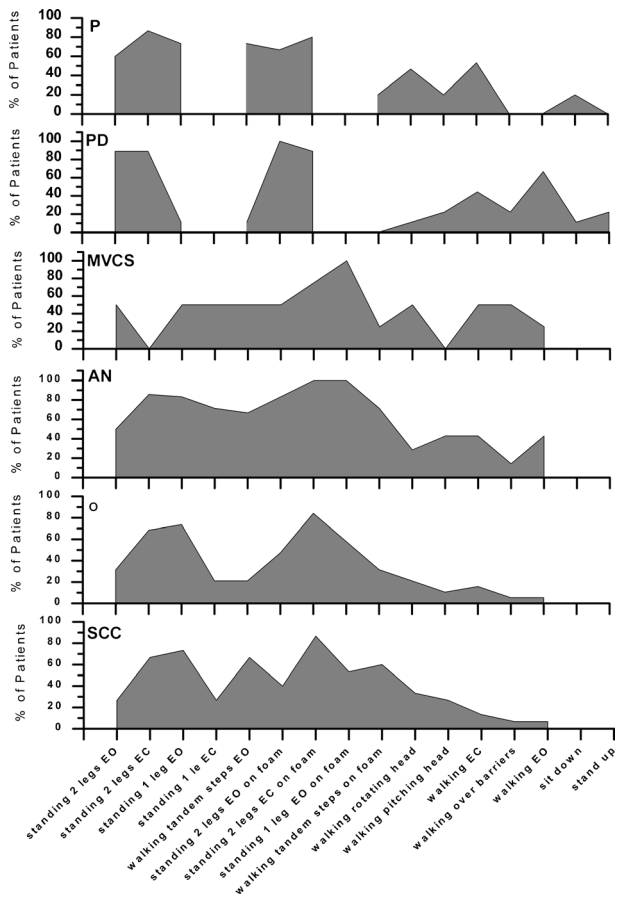

FIG. 5. Percentage of patients with a pathologic body sway during the conditions of the Standard Balance Deficit Test. Patients were analyzed within the following subgroups: P, presbyvertigo; PD, Parkinson's disease; SCC, semicircular canal paresis; O, otolith disorder; AN, removal of an acoustic neuroma; MVCS, micro(neuro) vascular compression syndrome. P and PD patients performed the geriatric Standard Balance Deficit Test where the "standing on 1 leg EC" and the "standing on 1 leg EO on foam" tasks were replaced by "sit down" and "stand up." All other subgroups performed the Standard Balance Deficit Test, which not includes the "sit down" and "stand up" tasks.

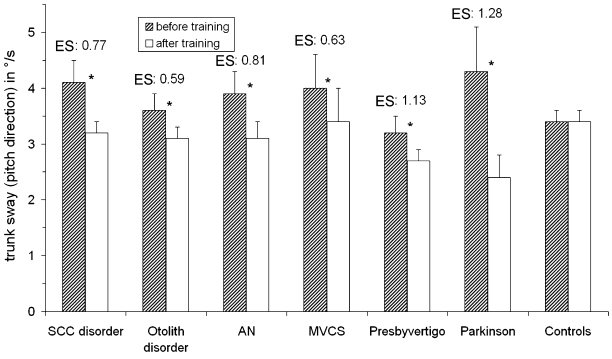

FIG. 6. Mean values (±SEM) of the body sway in pitch direction before and after a vibrotactile neurofeedback training in treatment subgroups. *Asterisks* indicate significant differences. ES indicates effect size.

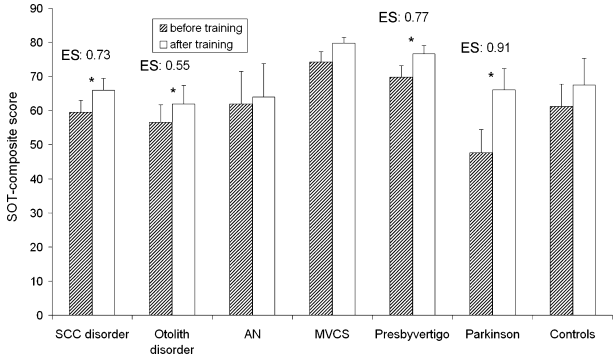

FIG. 8. Mean values (±SEM) of the SOT (BalanceMaster/ Neurocom) before and after a vibrotactile neurofeedback training in treatment subgroups. *Asterisks* indicate significant differences.

The reliability and clinical relevance of the results could be proven by a power value of approximately 1 and an effect size of more than 0.6. Moreover, the improvement was present only in patients of the feedback-training group compared with the controls. The finding that training with a sham device had no influence on body sway is in contrast to earlier studies, which investigated the effect of physical exercises in healthy subjects (19). It could be possible that the training sessions of the present study were too short to induce such learning effects by repetition. Each of the exercise was repeated only 5 times for 20 seconds in the daily sessions. This is in line with previous studies of short training sessions in everyday-life conditions, which had no significant effect on the postural stability without applying an additional feedback signal during the training (15).

The underlying neural mechanisms for the training effect might involve operant learning (20) and the multisensory convergence of enhanced processing of different sensory modalities (21). When the patients' reactions to the vibrotactile feedback signal result in a reduction of trunk sway, they have to memorize the activation template of the proprioceptive system for this situation. Without vibrotactile feedback, the activation template of the proprioceptive system has to be maintained at the same level to ensure postural control. Those neural structures encoding more than one sensory modality are best suited for spatial information processing (22). In primates, the parietal cortex seems to play a key role in this procedure (23).

However, each learning process should be followed by unlearning. The improvements induced by the vibrotactile training in the present study also were observed after a 3-months' follow-up. Although, all patients were invited to the follow-up measures, only 60% attended. One reason or implication is that 40% of the patients had no further interest in the study because his/her vestibular problems disappeared after the training. It is a very frequent effect in clinical practice. If this holds true, only patients with consisting vestibular problems were included in the follow-up measures. The effect of the training is possibly much higher than reported after 3 months.

The observed long-term effect is in line with earlier studies in chronic unilateral vestibular hypofunction or in PD where only a small number of supervised sessions were sufficiently enough to obtain a long-lasting improvement of postural stability (3,6).

The vibrotactile neurofeedback signal seems to be a very effective stimulus for vestibular rehabilitation

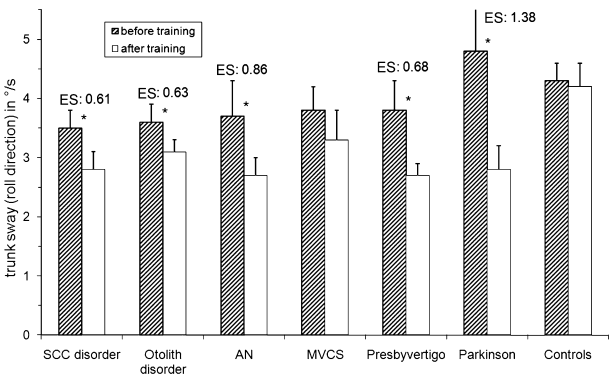

FIG. 7. Mean values (±SEM) of the body sway in roll direction before and after a vibrotactile neurofeedback training in treatment subgroups. *Asterisks* indicate significant differences.

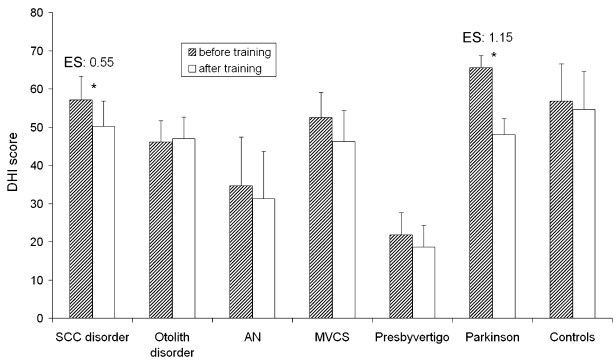

FIG. 9. Mean values (±SEM) of the DHI before and after a vibrotactile neurofeedback training in treatment subgroups. *Asterisks* indicate significant differences.

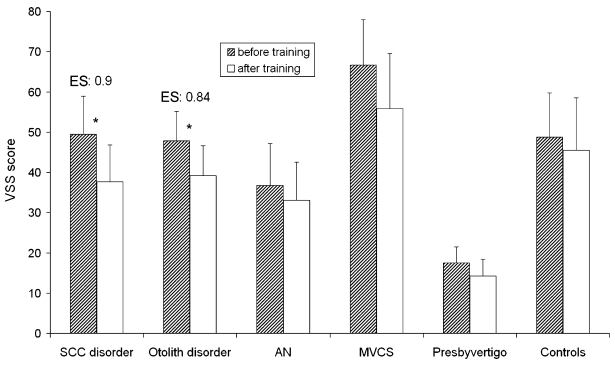

FIG. 10. Mean values (±SEM) of the VSS before and after a vibrotactile neurofeedback training in treatment subgroups. *Asterisks* indicate significant differences.

because its perception by the patients during the training is very intuitive. Furthermore, no important, other sensory input channels (e.g., auditory, visual) are impaired by the vibrotactile signal so that no sensory conflict occur, and the signal processing is not influenced by simultaneous vestibular stimulation (as known for auditory signals [24]). However, a vibration-induced illusion of movement was described in previous studies (25), but the strength and duration of vibration, which is necessary to induce such effects, cannot be provided by the vibrotactile feedback system used in the present study (Vertiguard). The vibrotactile stimulation applied with the Vertiguard was very short (approximately 1 s) and only slightly above the perception threshold. If there is nevertheless an influence of the vibration itself on some trunk muscle reflexes, these reflexes would act in the same direction as intended by the training (move to the opposite site) and would therefore support the intended application of the device.

The subjective parameters—such as DHI and VSS scores—were significantly reduced with a high statistical power and effect size in the treatment group only. The controls showed a small, but not significant, reduction of these symptom-related scores. This is somewhat surprising because the dissociation between self-perception and actual vestibular handicap was reported previously (26,27).

Treatment Subgroups

The broad distribution of training tasks within each subgroup indicates the need of an individualized training program, which is based on a standardized body sway analysis. This holds true even if some tasks were more frequent pathologic in 1 subgroup than in another subgroup. The most frequent pathologic tasks were quite similar in all subgroups. Therefore, it seems not to be possible to develop a specific training procedure for specific pathologies with this method.

The analysis of disease-related subgroups within the total treatment sample showed different training effects in some of the investigated parameters. Even if body sway during everyday life conditions could be significantly reduced in all subgroups, patients with PD or presbyvertigo showed the highest absolute reduction. The high efficacy of the neurofeedback training in these subgroups is possibly related to the fact that central compensation could occur without pathologic inputs of the peripheral vestibular organs. This hypothesis is supported by the present results of the SOT on the BalanceMaster (stance conditions). Patients with an irregular input of peripheral vestibular afferents (e.g., MVCS subgroup) showed a nonsignificant improvement. In these patients, the peripheral vestibular afferents depend largely on variable parameters such as blood pressure and pulse rate, which in turn trigger the functional status of the corresponding artery—that is, the anterior inferior cerebellar artery.

The results of the investigated subjective parameters differed between the subgroups. Only patients of the SCC group showed a significantly decreased DHI and VSS score after the training. The VSS scores, but not the DHI scores, were decreased in patients with an otolith disorder. This is in accordance with previous results of auditory neurofeedback training in those patients (15).

The highest reduction of symptom scores, combined with the largest statistical power and effect size, was observed in the PD group. However, the mean values of these patients before and after the training was the highest of all investigated subgroups. The subjective parameters (VSS/DHI) of the P group were not significantly reduced even if the objective decrease of body sway was statistically significant. On the one hand, this could rely on a correlation between the absolute changes of the scores and the low pretraining values. The overall extent of reductions in DHI scores was, for example, 11.9% for the SCC group (statistically significant) and 14.8% for the P group (not statistically significant). On the other hand, the dissociation between self-perception and postural handicap holds possibly particularly true for the elderly (26,27).

In essence, the vibrotactile neurofeedback training applied in the present study is a highly efficient method for the reduction of body sway in different balance disorders. Because the rehabilitation program is easy to perform, not exhausting and time saving, elderly patients and those with serious, long-lasting balance problems also can participate successfully.

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