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Eduardo Martin-Sanz, Isabel Ortega Crespo, Jonathan Esteban-Sanchez & Ricardo Sanz

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RESEARCH ARTICLE

Postural stability in a population of dancers, healthy non-dancers, and vestibular neuritis patients

Eduardo Martin-Sanz, Isabel Ortega Crespo, Jonathan Esteban-Sanchez and Ricardo Sanz

Department of Otolaryngology, University Hospital of Getafe, Madrid, Spain

ABSTRACT

Introduction: Several studies have indicated better balance control in dancers than in control participants, but some controversy remains. The aim of our study is to evaluate the postural stability in a cohort of dancers, non-dancers, compensated, and non-compensated unilateral vestibular neuritis (VN).
Methods: This is a prospective study of control subjects, dancers, and VN patients between June 2009 and December 2015. Dancers from the Dance Conservatory of Madrid and VN patients were referred to our department for analysis. After the clinical history, neuro-otological examination, audiogram, and caloric tests, the diagnosis was done. Results from clinical examination were used for the categorization of compensation situation. A computerized dynamic posturography was performed to every subject.
Results: Forty dancers and 38 women formed both 'dancer' and 'normal' cohorts. Forty-two compensated and 39 uncompensated patients formed both 'compensated' and 'uncompensated' cohorts. Dancers had significantly greater antero-posterior (AP) body sway than controls during condition 5 and 6 in the Sensory Organization Test (SOT) ($p < .05$). When we compared the uncompensated cohort with both control and dancers groups, we found significant greater body sway in every SOT studied condition ($p < .05$). While mean AP body say in SOT 5 and 6, showed greater values in compensated patients than the control group, the mean analysis did not show any statistical difference between the compensated and dancer groups, in such SOT conditions.
Conclusions: Dancers demonstrated greater sways than non-dancers when they relied their postural control on vestibular input alone. Compensated patients had a similar posturographic pattern that the dancers cohort, suggesting a similar shift from visual to somatosensory information.

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Balance; dance; vertigo; dynamic posturography

Introduction

Postural stability during locomotion is an essential motion act which provides on a daily basis standard functional tasks, and specialized coordination movements such all those needed for sport and dance [1].

The postural control regulates the body's sway by integrating somatosensory, visual, and vestibular feedback information. The complexity of the motor tasks for healthy subjects could be defined as the number of the system components (vestibular, somatosensory, and visual network) affected during such movement.

Studies on postural control through posturography systems have been commonly focused on static posturography tests and sensory organization tests using computerized dynamic posturography, in which the subjects must maintain the upright position in situations of sensory restriction situations.

Ballet dancers exhibit high levels of expertise in quality movement control and balance [2]. Several studies have described better balance control in dancers than in the control group [3,4]. Based on this premise, is the finding when vision is permitted, ballet dancers are significantly more accurate at spatial positioning of the limbs than non-dancer controls [5]. Nevertheless, some controversy remains regarding postural control in dancers. Other authors report when visual cues are available, expert gymnasts are not more stable than experts in other non-gymnastics sports, while maintaining quiescent upright postures [6].

It has been proposed that ballet training produces a shift from visual information which depend on somatosensory information, originated from the feet to the lower part legs [7,8].

This notion is based on the empirical finding that ballet dancers reveal greater postural stability than non-dancer control, when they maintain standing position quietly with closed eyes [4,9].

Simmons [10] reported less stability in dancers than in controls, when alone somatosensory information or in combination with visual information was made unreliable, with a predominance of hip strategy to maintain postural control.

Indeed, there is a large casuistry of evidence which indicate that individuals having unilateral labyrinthine deficit becomes more unstable and experiences greater oscillopsia when moving within visually demanding environments such as busy streets and supermarkets.

Vestibular neuritis (VN) patients complain of acute onset of persistent rotatory vertigo with oscillopsia, gait, and

CONTACT Eduardo Martin-Sanz emartinsanz@gmail.com Department of Otolaryngology, Hospital Universitario de Getafe, Autovía de Toledo, km 12,500, 28905 Getafe, Madrid, Spain

postural imbalance, tendency to fall, nausea, and/or vomiting. The signs and symptoms of VN solve within weeks in most of patients through peripheral functional improvement process and central compensation. However, an average score around 20% of patients will continue to experiment chronic postural imbalance and vertical oscillopsia [11].

The aim of our study is to evaluate the postural stability in a cohort of dancers, non-dancers, a compensated unilateral VN and non-compensated unilateral VN. We hypothesize that dancers, compared with non-dancers, would exhibit a smaller amount of sway. We further expect that those vestibular patients should have bigger sway area possibly reflecting their greater postural instability.

Methods

This is a prospective study of healthy non-dancers subjects, dancers, and vestibular patients, performed between June 2009 and December 2015. The procedures followed were in accordance with the Declaration of Helsinki 1975.

Non-vestibular subjects

Two cohorts of normal subjects were included in the study. The dancers cohort came from the Dance Conservatory of Madrid and International School of Dance of Madrid. Which is the same knowledge and skills such as 'The Royal Ballet School' in Classical Ballet, and 'The Imperial Society of Teachers of Dancing (ISTD)', in Classical Ballet and modern Dance disciplines. All dancers were trained in Classical Ballet for 15 years. The cohort of non-dancers subject served as a control group and was not trained in any other balance tasks.

Vestibular patients

Two cohorts of vestibular patients were included: subjects were outpatients referred to our department due to vertigo. After a detailed clinical history and complete neuro-otological bedside examination, audiogram and caloric tests were done. Patients were not included if incomplete or uninterpretable data were obtained either at the clinical exam or in caloric/rotatory testing. Patients were also excluded if older than 30 years old, in order to maintain the same requirements as dancers which allow comparison.

The diagnosis of VN was obtained by fulfilling the criteria for inclusion: (1) a single acute onset of prolonged vertigo, (2) unidirectional mixed horizontal–torsional spontaneous nystagmus to the healthy side, (3) canal paresis greater than 25% in the affected ear measured by VNG, and (4) exclusion of stroke, dementia, Parkinson disease, multiple sclerosis, diffuse axonal injuries, and cognitive deficit [12].

Signs and symptoms at clinical examination used for the categorization of compensation situation were the spontaneous nystagmus, head-shaking nystagmus, and the persistence of lateropulsion. If any of those signs were present, the patient was included in the non-compensated cohort. Otherwise, patients were included in the compensated cohort.

Caloric stimulation

The caloric stimulation test was only performed in vestibular patients. The bithermal caloric test was performed according to Fitzgerald and Hallpike. Each ear was irrigated alternatively with a constant flow of water at 30 °C and 44 °C during 40 seconds. The response was recorded over 3 min and a 7-min interval between each stimulus was respected to avoid cumulative effects. A video based system was used (Ulmer VNG, v. 1.4, SYNAPSIS, Marseille) to acquire and analyze the eye response. The head position was checked before each irrigation to maintain the LSC close to 'earth-vertical', and patients alertness was maintained by asking the patient to make mental arithmetic throughout the recording.

The maximum slow-phase velocity (SPV) of nystagmus after each irrigation was calculated, and canal paresis was determined according to Jongkees formula. In our lab, a canal paresis (CP) of greater than 25% is considered significant and informative as a pathological sign.

Computerized dynamic posturography (CDP)

CDP (Equitest, NeuroCom International, Inc., Clackamas, OR) was carried out with the SOT battery. In this test, the patients were asked to maintain their balance under six different conditions. The first three conditions (SOT 1, SOT 2, and SOT 3) provided accurate uninterrupted foot support surface information. The visual information provided is different in each of the three conditions. In SOT 1, the patients remain with their eyes open whilst in SOT 2 they must have their eyes closed. In SOT 3, the patients must remain with open eyes but the surroundings move in a stimulated pattern by the antero-posterior (AP) swaying movements which he or she continuously performs. In SOT conditions 4, 5, and 6, the visual scenario corresponds to that described for SOT 1, 2, and 3, respectively, but in each of them, the A-P sway movement of the patient drives the movement of the supporting surface in an axis parallel to the ankle joint. For every SOT condition, several trails were performed; in each of them, the A-P sway was measured, valuated and calculated relative to a sway of 12.5° (which is considered the maximum A-P sway about the ankle joint in normal subjects). In terms of general performance, a composite score (CS) was given as an overall estimate of postural stability, and is a weighted average of the results in different trails with special emphasis placed on the conditions SOT 3 through to SOT 6.

Statistical analysis

Assumption of normality of the data distribution was evaluated with the Kolmogorov–Smirnov method with Lilliefors correction. Every variable was normally distributed.

A multivariate analysis of variance (MANOVA) was performed to evaluate the meaning of SOT differences among the four groups of patients. A post hoc analysis with Tukeys'test was used for multiple comparisons. Significance was established at $p > .05$. SPSS 19.0 (SPSS Inc, Chicago, IL) was used for al statistical evaluation.

Results

Forty dancers and 38 healthy young women formed both 'dance' and 'normal' cohorts. Forty-two compensated VN patients and 39 uncompensated patients formed both 'compensated' and 'uncompensated' cohorts.

As shown in Table 1, comparisons for age, weight, and height indicated no significant differences among the four groups ($p = .002$). Analysis of the six SOT balance scores (Figure 1) revealed significant differences among the four groups, F (6, 152) = 3.96, $p = .001$.

Post hoc analysis revealed that dancers had significantly ($p = .021$) greater AP body sway than controls during SOT 5 and SOT 6. There was no statistical difference in AP sway between dancers and normal subjects for SOT1 through SOT 4. Regarding the differences between both normal groups (control and dancers), the dancers did not show better postural stability than non-dancers in anyone of the studied conditions. Although SOT 2 through SOT 4 conditions showed better scores in the dancer group than the normal subjects, those differences were not statistically significant.

Table 1. Mean and standard deviations of weight (kg) and height (cm) for every studied cohort.

	Normal	Dancers	Compensated	Uncompensated
Weight (kg)	167.76 ± 0.62	167.15 ± 0.53	165.85 ± 0.56	168 ± 0.45
Height (cm)	55.63 ± 1.03	54.7 ± 0.32	57.5 ± 0.86	57.82 ± 0.64
Age	24.3 ± 2.2	26.1 ± 1.8	27.7 ± 2.4	26.9 ± 2.1

When comparing the uncompensated cohort with both control and dancers groups, we find out significant greater body sway in every SOT studied condition. Postural sway in the compensated cohort did not show significant differences with both normal and dancer population for SOT 1 through SOT 3 conditions.

Nevertheless, the compensated patients group had significantly greater body sway than the rest of the groups in SOT 4 ($p = .020$). While mean AP body say in SOT 5 and 6 showed greater values in compensated patients than the control group, the mean analysis did not show any statistical difference between the compensated and dancer groups, in such SOT conditions (Table 2).

Discussion

Many conclusions can be drawn from the posturographic results; we observed in our four groups of patients. The first conclusion is that every subject of our whole population was significantly less stable when the somatosensory information was altered, and they relied their postural control on vestibular input alone (SOT 5 and 6).

Recall that sensory information from the plantar surface of the foot is important for postural control; for instance, force, pressure, and support surface qualities' information are encoded by plantar cutaneous afferents that are strictly linked to the CNS in order to reach body stability.

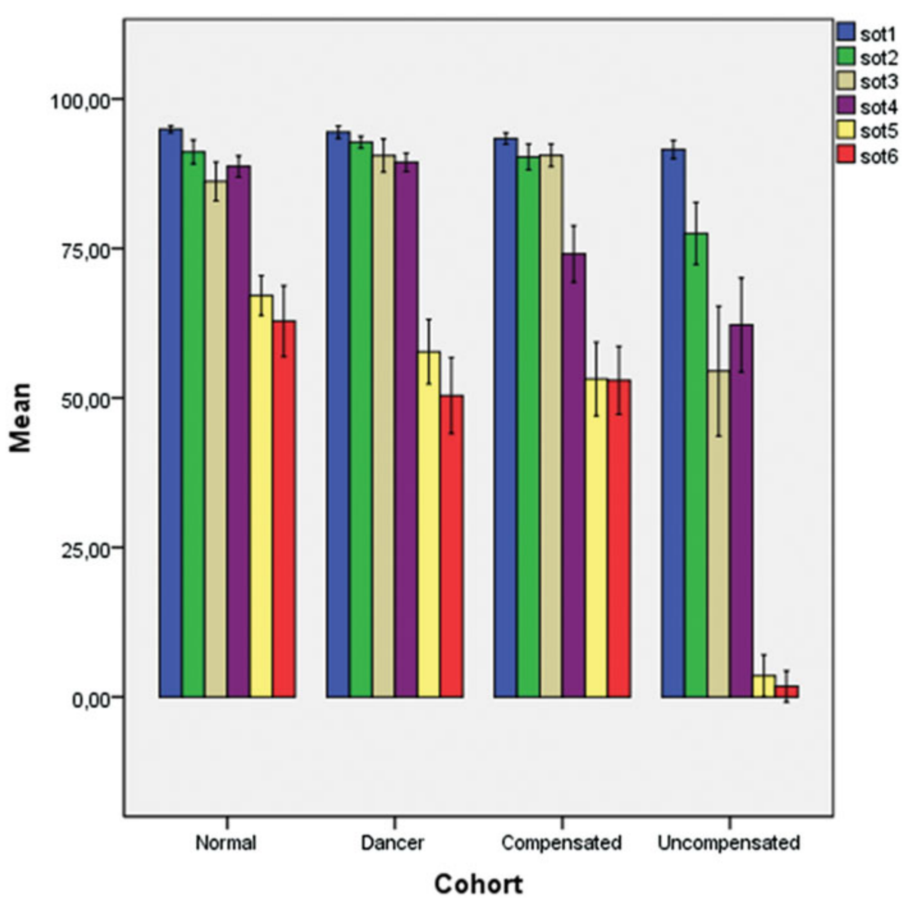

Figure 1. Error bar graphic representing each SOT conditions for the different cohorts of the study.

Table 2. Mean and standard deviations of antero-posterior postural sway in every SOT for every studied cohort. Below every column, *F* and *p* values of the multivariate ANOVA testing mean differences for every SOT condition among the different cohorts.

	SOT 1	SOT 2	SOT 3	SOT 4	SOT 5	SOT 6
Normal	94.94 ± 0.28	91.13 ± 0.98	86.21 ± 1.59	88.71 ± 0.88	67.13 ± 1.60	62.84 ± 2.93
Dancers	94.45 ± 0.51	92.77 ± 0.49	90.52 ± 1.36	89.40 ± 0.76	57.72 ± 2.67	50.40 ± 3.13
Compensated	93.38 ± 0.48	90.30 ± 1.06	90.57 ± 0.93	74.07 ± 2.33	53.16 ± 3.03	52.92 ± 2.81
Uncompensated	91.53 ± 0.75	77.51 ± 2.57	54.48 ± 5.36	62.20 ± 3.88	3.53 ± 1.7	1.76 ± 1.29
F	7.77	22.19	36.61	30.40	139.33	103.59
p	.000	.000	.000	.000	.000	.000

Of particular interest is the result for SOT 5 and 6, where experienced dancers have significant greater sways than non-dancers. Although several authors have reported better postural control in dancers than non-dancers [4,13], it has been hypothesized that the received training by dancers may have effect just during challenging conditions, and it cannot be transferred in less difficult balance conditions which is more representative of day-to-day life. As reported by other authors, based on our initial findings, it seems that balance training has a pervasive effect on postural control that does not appear only when balance is threatened [2].

A possible explanation is the larger role that vision seems to play at the dependence of other perceptual systems. Although some controversy is around the visual dependency of dancers [4,14], it is a fact that they learn strategies related to visual detection and regulation of self-motion, with a frequent use of mirrors and visual landmarks which might increase the importance of the visual input.

The present study employed dynamic posturography to determine how visual perception and support surface mobility affected postural stability, not only in ballet dancers and healthy subjects but also in VN patients with different compensation statuses. These findings may contribute in some extent to the rehabilitation of patients with vestibular impairment.

Any increase in body sway measured during standing on a moving platform with closed eyes is considered specific to vestibular disorders, since such patients have asymmetric distribution of postural tone and the role of vestibular inputs becomes increased with reductions in visual and somatosensory inputs [15] condition. As expected, when we compared our uncompensated VN patients with the rest of the cohorts, they had statistically significant greater body sways, not only in SOT 5 and 6 but also in the rest of the SOT conditions.

Patients with vestibular dysfunction feel unstable with closed eyes, consequently they maintain their stand-up position by using the active stability process relying on residual vestibular and proprioceptive inputs, which activate the muscle tone through the CNS [16]. Once a VN patient passes the acute phase of the vertigo attack, it is likely that age and residual vestibular function make a greater contribution to postural control [17], through the vestibular compensation.

However, the extent of vestibular compensation varies among VN patients. Since some patients show great improvement while the postural stability is using visual, proprioceptive and remaining vestibular information, it may be difficult to distinguish healthy patients from those with balance disorders, using the assessment of standing in the presence of somatosensory feedback. Actually, our group of compensated VN patients has a similar posturographic pattern that of the dancers cohort. The only significant difference in sway between these two groups relies on SOT 4, in which somatosensory information was unreliable. This condition caused that compensated VN patients experienced greater sway than dancers. It is remarkable that dancers and compensated patients groups had similar sways in SOT 5 and 6 conditions, in which both groups have significantly greater sway than the healthy non-dancer subjects.

These results suggest that dance training and vestibular compensation process results in a shift in sensory weighting from visual to somatosensory information. Meanwhile, our compensated patients did not perform any vestibular rehabilitation, we can only attribute this improvement of the body sway to the vestibular compensation process in itself.

Nigmatullina et al. [18] reported a reduced grey matter density in the vestibular cerebellum of dancers, which was correlated with dancing experience. This volumetric reduction is attributed to the effort to suppress dizziness during the early stage of training.

We hypothesize that a similar process could explain our posturographic findings in both dancers and vestibular compensated patients. Fetter et al. [19] followed the period of recovery after an acute unilateral vestibular lesion and showed that the postural sway measured by dynamic posturography recovered within a few weeks even in patients with persistent unilateral vestibular lesions. Nevertheless, there are patients with poorer prognosis, such as elderly adults, patients with neurologic, or orthopedic diseases who could benefit from an individualized vestibular rehabilitation program.

In dance training and performance, mental imagery of movement is frequently used as a tool for learning and optimizing movements. Probably these motor strategies are determined by the specificity of the training for the dance, like the use of mirrors and continuous visual control [20]. The findings of this study could have important implications for dancers, teachers, and medical staff, allowing them to include their experience to enhance the improvement of some vestibular impaired patients.

Further studies are required with larger numbers of patients and a longer follow up period. The analysis of the posturographic evolution in VN patients along the time would enhance the comprehension of the vestibular compensation process and its application to rehabilitation

Conclusions

Dancers experienced greater sways than non-dancers when they relied their postural control on vestibular input alone. Compensated patients had a similar posturographic pattern that of the dancers cohort, suggesting a similar shift from visual to somatosensory information.

Disclosure statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The authors declare that there is no conflict of interest.

ORCID

Eduardo Martin-Sanz http://orcid.org/0000-0003-1175-3844
Jonathan Esteban-Sanchez http://orcid.org/0000-0002-6184-6830
Ricardo Sanz http://orcid.org/0000-0002-4990-8859

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