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Case Series

Postural Control in Static Equilibrium after Different Receptor Stimulations: A Comparison of three Case Studies

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Abstract

Objective: Training allows athletes to acquire different balance control skills based on the discipline practiced. In particular, dance, in the motor field, allows dancers to optimise the coordination skills that can improve balance and postural stability. The present study compared the postural tonic system control abilities of a semi-professional dancer (SD), a competitive judoka (CJ) and a control case (CC), under static equilibrium conditions. The subjects, selected according to homogeneity criteria, were subjected to tests in a bipodal position on a stabilometric platform and evaluated after different stimulations.

Results: The data relating to the quantity of body oscillations and the displacement surface of the centre of pressure (CoP) calculated in cm2 were compared. It emerged that the SD was not able to use vestibular afferents in a static position like the other two subjects; only after the test in which the proprioceptive receptor was differentiated, the SD reported a number of oscillations amount to 11.6 times less than the CJ and 4.5 times less than the CC.

Conclusions: According to the results obtained, the dancer implements different strategies compared to non-dancers for maintaining static balance; preferably she uses visual and proprioceptive afferents, minimising the inputs from the vestibular system.

Keywords: Stability; Postural Control; Static Balance; Vision; Proprioception; Vestibular System; Dancers; Judoka; Sport

Introduction

Dance is undoubtedly one of the most fascinating forms of human expression, whose form in its highest sense communicates all the complexity of the motor gesture [1]. It is therefore recognised as a perfect combination of art and sport, since it places high demands on the musculoskeletal system of dancers, influencing their motor and postural behaviour [2]. The dancer's performance is characterised by a large number of elements, such as strength, balance and flexibility [3]. High control of the postural tonic system is essential, both to achieve the optimal aesthetic levels that dance requires, and to reduce exposure to the risk of injury [4].

The dancer's sophisticated static and dynamic balancing skills are highlighted in the world of sport in general: dance itself is used in different protocols to improve the balance of "*non-dancer*" athletes [5]. From this, dancers could be expected to possess a high sense of awareness in terms of the positioning and movement of their bodies in space and consequently, superior overall balancing abilities, compared to categories of non-dancing subjects [6].

The performance environment entails that the dancer appears in front of the audience and dances on different stages, which are sometimes sloping and with different lighting, depending on the place in which it is located. Just think of how confusing visual references can be due to poor lighting or an excessively inclined stage [1,7]. This is why several studies have stated that dancers are able to perform a sensory shift mechanism that allows them to favour the use of visual information, rather than the information provided by the somatosensory system, when they are in the environmental context in which it is necessary to make the switch from one receptor system to another for motor control [8,9]. However, Giboin., *et al*. have shown that in dancers, receptor activation for the control of the postural tonic system in equilibrium conditions in simple positions differs from that of non-dancers [8]. In fact, Hugel., *et al*. argue that balancing skills developed through dance cannot be transferred to the (less demanding) balancing conditions that are more typical of daily living activities [4].

This is certainly why there is a great deal of debate in the literature in which some authors claim that dancers have inferior postural control and balance abilities compared to non-dancers, and others on the other hand claim exactly the opposite. Perrin., *et al*. argue that dancers are dependent on the visual system, as they train every day leaning against a barre and in front of the mirror [10]. In this way, according to other studies, visual afferences tend to prevail, to the detriment of proprioceptive ones that are inhibited, limiting the development of kinesthetic awareness and the ability to judge based on one's proprioceptive sensations, due to the two-dimensional image reflected in the glass [11]. Golomer., *et al*. on the other hand, point out that unlike non-professionals, professional dancers are less dependent on the visual system for postural control, which is used only to take reference points in the surrounding space and to activate the eye-vestibular reflex after performing dynamic gestures such as jumps and/or spins [12].

Simmons examined the neuromuscular response and proprioceptive sensitivity of dancers during balance tests, concluding that, when observed with greater muscle activation, they exhibited better *balance* skills, thanks to proprioceptive afferences [13,14]. Golomer., *et al.* conclude by stating that experience and maturity in the dance learning process presumably shifts sensorimotor dominance from vision to proprioception [12].

However, it is not yet clear what strategy dancers use to control postural stability in static equilibrium and how that strategy differs from the *non-dancer* population [15]. Therefore, the objective of the present study is to analyse the behaviour of the participants in response to the various receptor stimuli.

Participants

It was considered essential to select participants excluding individuals with any sort of pathology and who never had serious bone fractures that could have compromised the outcome of the tests. Subjects who wear orthotic insoles or other devices that could affect posture have not been included as well.

The 3 participants were selected according to the homogeneous criteria of age, sex, BMI, body composition and plantar support and completed three balance tests in a bipodal erect station on a stabilometric platform.

The subjects were also subjected to useful questions in order to identify other homogeneous characteristics related to sports habits and their physical health status at the time of data collection, also as it was interesting to analyse some details of each participant's clinical history.

At the time of data collection, none of the three subjects had injuries [16]. The 17.7-year-old semi-professional (SD) dancer trains 5 days a week for an average duration of 1.30 hours per day; she has astigmatism with visual correction (she wears glasses) only at home, during study and while watching TV, but not during training.

The 17.3-year-old competitive judoka (CJ) also trains 5 days a week for an average duration of 1.30 hours per day. She also has astigmatism with visual correction (she wears glasses) but not during training.

The 18.1-year-old control case (CC) is an untrained subject, who has never practiced dance or sports based on balance training. She always wears glasses and is short-sighted and astigmatic.

Tools

Body composition data were calculated using the orthostatic electrical bioimpedance tool "*Inbody 120"*, together with anthropometric data on weight, height and BMI [17].

The parameters of plantar support, surface and oscillation length were obtained through the use of the stabilometric and baropodometric platform "*Currex Footplate*" [8]. Each test lasted 10" and was repeated 3 times with a recovery of 60" between the *steps* to avoid muscle fatigue; the test in an erect monopodal station with open eyes after performing the ten 360-degree turns on the spot was performed after a maximum of 5 seconds from the execution of the same turns [7,18].

The outcome of the instrumental examinations

The parameters. Type of plantar support, distribution of weight between right foot and left foot, as well as between the rear foot and forefoot, together with the positioning of the centre of body mass, were the parameters taken into account by the baropodometric examination in bipodal erect station. The lateral-medial oscillations (X) and antero-posterior oscillations (Y) of the body and the displacement surface of the CoP, are instead the parameters taken into account by the stabilometric examination in the different receptor stimulations.

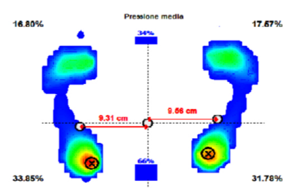
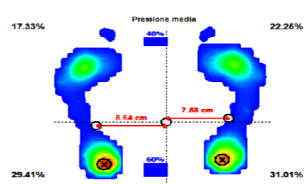
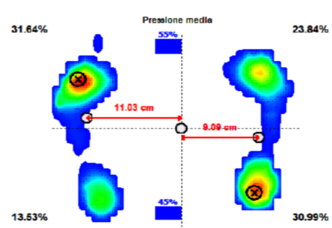
Judoka	
Control Case	
Semi-professional dancer	

Table 1: Baropodometric examination.

Baropodometric examination The baropodometric characteristics of the three participants are indicated in Table 2. It is noted, as the subjects have in common a plantar support of the cavus type. In the dancer's foot, in particular, the isthmus of conjunction between the rear foot and forefoot is very thin, so much so that it almost disappears at the level of the heel, determining the presence of a cavus foot with valgus back foot.

The differences regarding the characteristics of the pressure points distributed on the soles of the feet are notable. It is noted that the dancer's centre of mass is positioned by perfectly distributing the weight in equal parts between right and left foot, forefoot and rear foot (50% per part). In reality, as can be seen from the baropodometric examination of the other two participants, the centre of mass should be correctly positioned further back by distributing the weight between 60% on the rear foot and 40% on the forefoot. This means that the dancer has a forward imbalance of the torso, justified by the fact that the dancers dance mainly on the tips and half tips of the feet, favouring a metatarsal support. Considering that, even in judo, practitioners tend to train with weight on the forefoot, on baropodometric examination, unlike the dancer, the plantar pressure points in the judoka appear well distributed.

The stabilometric examination. As can be seen from graphs 1, 2 and 3, in the open-eye (OE) bipodal position tests, it was possible to observe the dancer making the lowest total number of oscillations, both on the antero-posterior plane (Y) and on the lateral-medial plane (X). The same, however, in the absence of visual inputs, in all the parameters taken into account, showed a lower postural stability, both with respect to the control case and with respect to the judoka. Note how, in general, in test no. 2 (EC), in which the efficiency given by the combination of vestibular and proprioceptive receptors is differentiated, the dancer demonstrates a lower stability than the control case, given the greater amount of antero-posterior oscillations (Y) and the increased displacement surface of the CoP. In test no. 3 (OCCV), in which the visual and proprioceptive system was stimulated, with the aim of differentiating the vestibular system, it is again noted how the dancer performs the greatest number of oscillations compared to the other two participants.

Test no. 4 (OC10G) was decisive: the surprising data was obtained by comparing the values of the area relative to the movements of the CoP between the three subjects. The total amount of oscillations of the dancer after stimulation of the vestibular and visual systems was 11.6 times lower than in the judoka and 4.5 times lower than in the control case. In the OC10G test, the pure data relating to the efficiency of proprioceptive receptor inputs was obtained: a significant *gap* highlights the difference in receptor strategy between the dancer and the other two subjects.

Materials and Methods

The parameters of body oscillation with respect to the length of the displacements on the antero-posterior (y) and lateral-medial (x) plane and the surface of the oscillations of the centre of body pressure (CoP) were examined.

The tests carried out were as follows

- Erect bipodal station with open eyes (OE) to differentiate the functionality of the visual, vestibular and proprioceptive receptors.
- Erect bipodal station with closed eyes (CE) to differentiate the functionality of the proprioceptive and vestibular systems in the absence of visual inputs.
- Erect bipodal station with closed eyes, on proprioceptive pillow, after visual stimulation (OCCV) to differentiate the functionality of the vestibular receptor.
- Erect bipodal station with eyes closed after performing ten 360° turns on the spot (OC10G) to determine proprioceptive receptor functionality.

Results

Physical characteristics of the participants

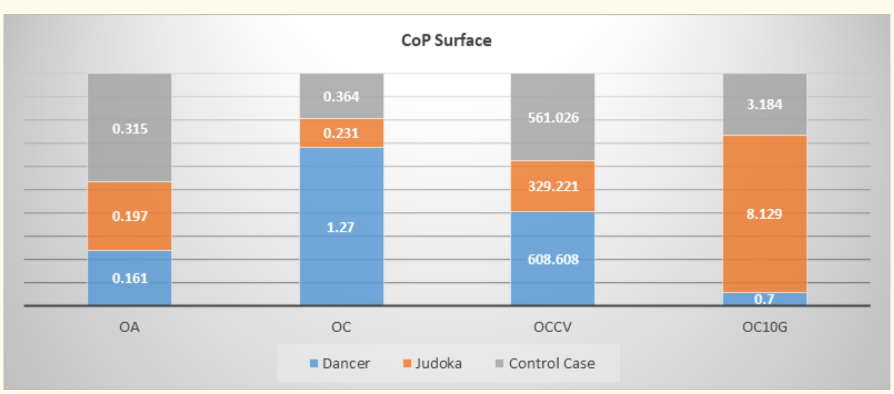
The physical characteristics of the participants are shown in Table 2. The dancer has a significantly lower total body mass and muscle mass than the other two subjects; the parameters of height and BMI are also lower compared to the control case and the judoka.

	Dancer	Control Case	Judoka
Age	17,7	18,1	17,3
Weight in kg	58,7	68,4	76,6
Height in cm	168	169	172
Body Mass Index	20,8	23,9	25,9
Lean Mass kg	27	25,4	34,5
Fat %	17,1	31,7	19,8
Body Water L	35,5	34,1	45,1

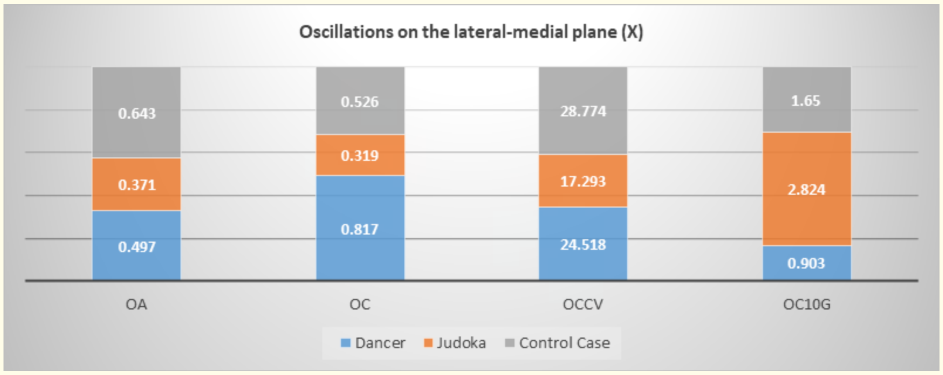
Table 2: Physical Characteristics of partecipants.

Analysis of results

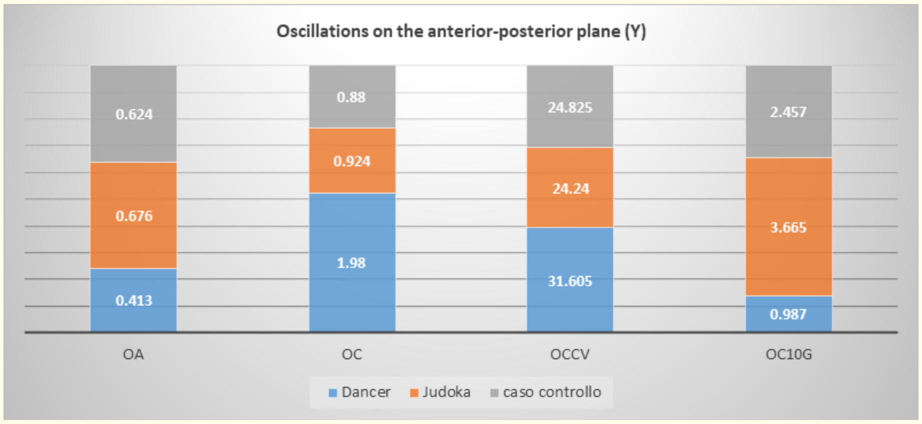
This study compared three cases: a dancer, a judoka and a control case. It was found that in the open-eyed bipodal position, in which the functional integration of the visual, vestibular and proprioceptive receptors was evaluated, the dancer presented a little reduced number of oscillations compared to judoka and almost 2 times less than the control case. In the test that differentiated the combined functionality of the vestibular and proprioceptive receptors, the dancer presented a score 3.4 times greater than the control case. In general, unlike the dancer, the judoka demonstrated a more consistent and high postural control in all the tests, except in the test in which proprioception was differentiated (OC10G), presenting a number of total oscillations equal to more than double compared to the control case and 11.6 times greater than the dancer.



Graph 1: Comparison of the displacement surfaces of body mass between tests 1, 2, 3 and 4.



Graph 2: Comparison of the number of oscillations on the lateral-medial plane between the tests 1, 2, 3 and 4.



Graph 3: Comparison of the number of oscillations on the anterior-posterior plane between the tests 1, 2, 3 and 4.

Discussion

According to Perrin., *et al*. the postural instability of dancers, deprived of the use of visual inputs, is due to their extreme dependence on the visual system, which is why they use the inputs specifically to regulate their postural control, to the detriment of proprioceptive afferents [10]. Contrary to the present study and according to the data collected, the dancer has demonstrated greater ability to balance not dependent on the visual system, but on the proprioceptive system after vestibular stimulation; instead, there is agreement in differentiating efficiency, rather than dominance, by the visual system in the dancer, given the optimal results obtained from the stabilometric tests with EO and having demonstrated that, in the teaching of dance, there is a tendency to induce dancers to use visual inputs to take reference points in the surrounding space, as well as to express the artistry of the gesture [19].

Simmons., *et al*. in fact, underscore the efficiency of proprioceptive and visual inputs in dancers for the maintenance of balance, noting also that these athletes are able to perform a shift from visual afferents to proprioceptive ones, only when they dance “with their eyes closed”: this happens, for example, during pirouettes and/or jumps, gestures in which, as the vestibular system is stimulated, the dancers find themselves facing moments of transient blindness due to rotational and multidirectional movements specific to the gesture [2].

As far as vestibular inputs are concerned, it should be known that dancers present a reduction of grey matter in lobes VIII and IX of the vestibulo-cerebellar area [20,21], and important neuroanatomical structural changes concerning the areas of cerebellum, cingulate motor cortex, posterior thalamus, as well as posterior hippocampus and paraippocampus [22]. This means that dancers, thanks to the constant practice of motor gestures that they undergo, do not use vestibular afferents for the maintenance of static posture [20,23]. This does not mean that the vestibular system in dancers is hypofunctional, on the contrary: the dancers' vestibule is evidently hyperfunctional, but due to an adaptation induced by the discipline practiced, they do not use it to carry out less demanding motor tasks and compensate for its non-use through a further hyperfunction of proprioceptive and visual receptors [21,24]. In fact, in a very recent study by de Oliveira, where the high capacity of the vestibular system in dancers is highlighted, the way in which dancers are able to implement vestibulo-cervical and vestibulo-ocular reflexes is faster than in the rest of the population that has been studied [24].

The OC10G test of this study demonstrated this. It should be noted that the turns performed in the test are the equivalent representation of pirouettes, a dance-specific motor task, which is highly complex and regularly performed by classical dancers [25,26]. It is well known that the automation of a gesture puts in place a reduced amount of attention capacity for postural control: so the dancer, when she is in front of a stimulus, which her central nervous system recognises as already perceived and previously stored in a motor scheme, oscillates less [25,27,28]. Thus, dancers might be able to compensate for vestibular disturbances thanks to a higher level of specific motor adaptation, which stimulates the readiness of the proprioceptive receptor system, which predominates over the control of the postural tonic system in static equilibrium, contrary to what happens to non-dancers [13,29]. On the other hand, the judoka has also been shown to oscillate less in the closed-eye balance test, (a sport-specific condition that is typical of the discipline of judo).

From the results highlighted, the surprising data was obtained from the stimulation of the vestibular system, determining that the use that both categories of dancers and non-dancers make of the vestibular system is significantly different in the control of static and dynamic balance.

Conclusions

It has been found that the reading of sensory information by the dancer takes place mainly through the use of visual and proprioceptive afferents [30]; however, the intervention by the vestibular system during static equilibrium is reduced, probably due to an adaptive choice due to the activity of dance, which has led to neuroanatomical structural changes of significant importance in dancers [21,31]. It should be understood exactly whether the dancer actually uses the vestibular system less or uses the visual and proprioceptive system more than the vestibular system. It is also necessary to understand if dancers use less semicircular canals or information from semicircular canals that is integrated at the level of the vestibular nuclei together with proprioceptive and visual information where, due to the type of training practiced, the dancer can use more information from the visual and proprioceptive system.

It is a common opinion that a training parallel to dance, based on dance-specific exercises with eyes closed or lights off, is the ideal type of training to support dancers in favouring the mechanisms of sensory shift under vestibular stimulation in the absence of visual afferents. The studies also state that, practicing dynamic balance exercises such as slackline, could improve the use of vestibular afferents under visual and proprioceptive stimulation [24,32].

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