ORIGINAL ARTICLE

Balance assessment after altering stimulation of the neurosensory system

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ABSTRACT

Aim Posture requires fine integrative elaboration, performed by the central nervous system, of neurosensory information originated from the visual, vestibular and spinal circuit. Many perturbing agents can influence this elaboration and then the postural stability. Several studies have evaluated only the effect of a single agent on the postural control. The study analysed the perturbing effect of several external agents on the different sensorial circuits in terms of postural balance loss in orthostatism.

Methods The postural stability of 31 patients was evaluated with a static posturography platform in basal conditions and after exposure to an external agent in the following order: stroboscopic light projecting, mechanical rotations on a swivel chair, feet desensitization through ice, administration of an alcoholic drink at intervals which depended on the participant return to basic posturographic values. Tests were performed with open eyes (OE), closed eyes (CE) and reducing plantar perception through the use of a rubber pillow.

Results The stroboscopic light altered the postural control. The swivel chair disturbed only with CE. Ice and alcohol increased the oscillation area. The alcohol test had a significant reduction in postural control with OE compared to CE. The rubber cushion increased the oscillation area in all OE tests and with CE in alcohol and ice tests.

Conclusion The different agents did not trigger postural control deficits in the same way. A cold environment with psychedelic lights and the use of alcoholic beverages altered significantly the postural stability by influencing simultaneously all perceptions (visual, vestibular and somatosensory feedback).

Key words: central nervous system, postural balance, sensation disorders, vestibular, visual perception

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INTRODUCTION

Posture requires a fine integrative elaboration, performed by the central nervous system (CNS), of neurosensory information originated from the visual, vestibular and spinal circuit (1-4). The postural stability is regulated by "eso" and "endo" inputs. The first is defined as an external information that modifies the neurosensory response implied in standing posture control, the second as an internal body component that responds to external stress and provides the holding of the body position in the space. Three "eso-input" structures are known in the standing posture: eye, vestibule and feet. Several studies have evaluated the effect of a singular modifying agent on the postural control: alcohol (5), hypothermia (6), and alteration of foot perception (7) or just the different agents (8). No studies in literature have tried to assess the diversity of response of the neurosensory adaptation as the result of different external stimuli performing on the same subject.

The aim of this study was to analyse the perturbing effect of different external agents on different sensorial circuits in terms of postural balance loss in orthostatism in a young and healthy population. Moreover, the strategy that the CNS adopts to compensate external misleading sensitive information while maintaining the upright static position was evaluated. The first hypothesis to test was that every single external perturbing agent can modify significantly postural control. The second hypothesis was that, according to different altering sources, there are no differences in the modification of the body balance.

PATIENTS AND METHODS

Patients and study design

The study was performed from January 2019 to May 2019 at the Orthopaedic and Trauma Operative Unit, Department of Biomedical and Dental Sciences and Morpho-Functional Imaging, University of Messina, University Hospital G. Martino, Messina, Italy. Inclusion criteria were the patients aged between 18 and 40 without any neurological, ocular, vestibular, orthopaedic, metabolic or other pathological conditions that could influence postural stability, with "normal" body mass index (BMI) (between 19 and 24kg/m^2). Exclusion criteria were neurological diseases, previous lower limbs fractures, lower limb sprains which occurred in 6 months prior to the test, previous surgeries on lower limbs, muscular diseases, drugs intake that alter postural stability, migraine, gastrointestinal diseases (celiac disease, malabsorption, peptic ulcer, etc.); pregnancy, nursing and every cause of basal stabilometric alteration.

Thirty-one patients, 21 males and 10 females, met these criteria; the average age was 26 years (range 18 – 39 years). A "Vertigo VSP 400N" (Vertigo Static Platform) (Vertigo, Genova 2010) static posturography platform was used to evaluate the postural stability. Each patient was evaluated in basal conditions and after exposure to every single external perturbing agent in the following order: stroboscopic light projecting, mechanical rotations on a swivel chair, feet desensitization through ice and administration of an alcoholic drink at intervals which depended on the participant's return to basic posturographic values.

All the procedures described in the study and involving human subjects were implemented in accordance with the ethical standards established by the Helsinki Declaration of 1975 and subsequent amendments. An informed consent was obtained from all patients included in the study.

The study did not require an approval of the Ethics Committee.

Methods

Posturography tests. The Test of Balance (ToB) calculates the percentages of the sensorial interactions (visual, vestibular and somatosensory feedback) of postural balance using the posturography platform. The ToB correlates the data of area, length and angular speed, combining the data of test performed with open eyes (OE), closed eyes (CE), reducing plantar perception through the use of a rubber pillow. Normal ToB values are (9): 21.49%-57.55% for view, 18.32%-43.94% for vestibule, and 15.11%-48.65% for plantar proprioceptive perception. We also considered the area, length, and the ratio between length and area (L/A) posturographic values for the Status-kinesigram with OE and CE. L/A is the expression of the density of the Status-kinesigram, indirect and reverse index, as well as monitor of the proprioception (10). An upper limit of 200 mm^2 of the test T0 area with OE was established as an additional exclusion criterion (11).

Tests execution. Patients fasted for at least 3 hours and stood with bare feet on the platform. The room was illuminated by artificial light to reproduce the same conditions of the external environment and isolated acoustically to prevent noise pollution. The patients maintained a standing position with two centimetres between heels, feet 30° apart, arms straight at their sides, looking straight ahead at a red target located at a distance of 1.5 meters (12). Posturography test was performed after alteration of the visual component by projecting a strobe light, of the vestibular component through mechanical rotation of the participant, of the plantar receptor component by inducing hypothermia and further of the visual and vestibular components by administrating alcohol.

Strobo light test. Using the program "Windows Movie Maker", we created a video in which black and white screens alternate for 3 times per second, and then we projected it on a wall facing the participant, at a distance of 1.5 meters, through a strobe light.

Mechanical rotation test. Slow and mechanical clockwise rotations were applied to the participant seated on a swivel chair without armrests. Rotations were performed at a speed of about 10 seconds per revolution of 360°, for a total time of 2 minutes (13).

Plantar receptor desensitization test. A round container with a 40 cm diameter was filled with crushed ice and used to determine feet hypothermia, and an anaesthetic effect on mechanoreceptors. The patients put their feet in the container for 20 minutes (14), interposing a sheet between feet and ice to prevent burns from ice.

Alcohol administration test. A beverage with an alcohol content of 40° was used for the alcoholic administration test. The test contemplated a rapid intake of alcoholic substance. For dosing, the parameters were met based on the assumption that 0.32g of ethanol per kilogram constituting patient's weight is required in order for the test to be effective (15).

A digital breathalyser "Digital display alcohol breath tester" (HD TRADING sas, Vicenza, Italy) in accordance with the RoHs and CE marking, certificated by IMQ Milan, Italy (www.hdtrading.eu, June 2012) has been used to test the alcohol content of the participants after intake, so that everybody would reach their limit. The posturographic test has been performed 30 minutes after the alcohol intake, when the alcohol reaches the blood concentration of 0.02% (15).

Statistical analysis

The results were expressed as mean, median and standard deviation (SD). Statistical analysis of the difference in average was performed by using the Student t test. The alpha value of 0.01 was considered. Therefore, the value of $p<0.01$ was rated as significant.

RESULTS

The results of the OE tests showed an increased length of the stroboscopic effect (T0 207.9±58.5, strobe 318.2±99.3; $p<0.01$) and an increased value of L/A (T0 1.7±0.6, strobe 2.3±0.8; $p<0.01$); the swivel chair had not produced any significant changes, but a high standard deviation in the value area (T0 49.5, chair 801.1); the use of ice on feet showed an increased area (T0 134.8±49.5, ice 188.5±107.5; $p<0.01$) and a length (T0 207.9±58.5, ice 237.2±59.4; $p<0.01$); the use of alcohol showed an increased area (T0 134.8±49.5, alcohol 225.3±192.5; $p<0.01$) and a length (T0 207.9±58.5, alcohol 244.4±68.1; $p<0.01$) (Table 1).

The CE test results did not show any significant statistical variation for the strobe light effect, for the swivel chair and for the ice. A significant value of L/A, in a statistically valid percentage reduction, resulted after the alcohol effect (T0 1.7±0.8, alcohol 1.2±0.5; $p<0.01$) (Table 2).

Table 1. Stabilometric data with open eyes

Test	Average/Median (SD)			p (Area, Length, L/A ratio)
	Area (A)	Length (L)	L/A ratio	
T0	134.8/130.0 (49.5)	207.9/195.1 (58.5)	1.7/1.6 (0.6)	
Strobo	156.5/162.0 (70.4)	318.2/306.0 (99.3)	2.3/2.2 (0.8)	0.1/<0.01/<0.01
Swivel chair	303.2/145.0 (801.1)	222.6/213.0 (81.7)	1.5/1.5 (0.6)	0.3/0.3/0.2
Ice	188.5/155.0 (107.5)	237.2/228.0 (59.4)	1.6/1.5 (0.8)	0.01/0.02/.07
Alcohol	226.3/167.0 (192.5)	244.4/238.0 (68.1)	1.5/1.4 (1.5)	0.01/<0.01/0.2

The results of the eso-input showed changes to the stroboscopic effect, indicating a reduction in the percentage of the visual component (27±10.1 *vs* 12.3±7.5), and an increase of the vestibular component (20.3±5.4 *vs* 24.5±6.7) and touch (52.8±10.5 *vs* 63.3±9.3) ($p<0.01$). The swivel chair induced

Table 2. Stabilometric data with closed eyes

Test	Average/Median (SD)			p (Area, Length, L/A ratio)
	Area (A)	Length (L)	L/A ratio	
T0	225.1/181.0 (127.5)	316.7/293.0 (121.1)	1.7/1.4 (0.8)	
Strobo	NE	NE	NE	
Swivel chair	188.6/145.0 (97.0)	322.4/289.0 (107.5)	1.9/2.0 (0.7)	0.03/0.7/0.2
Ice	204.7/185.0 (108.8)	322.8/313.0 (105.9)	1.8/1.8 (0.7)	0.3/0.7/0.4
Alcohol	532.6/285.0 (732.0)	384.0/346.0 (159.0)	1.2/1.2 (0.5)	0.03/0.02/<0.01

NE, Not evaluable

an increase in the use of the vestibular component (20.3±5.4 *vs* 24.7±7.8; p <0.01) (Table 3).

Table 3. Stabilometric data of Test of Balance

Test	Average/Median (SD)			p (Area, Length, Length/Area ratio)
	Vista	Vestibule	Feet	
T0	27.0/29.0 (10.1)	20.3/20.0 (5.4)	52.8/52.0 (10.5)	
Strobo	12.3/11.0 (7.5)	24.5/25.0 (6.7)	63.3/63.0 (9.3)	<0.01/<0.01/<0.01
Swivel chair	24.9/26.0 (10.2)	24.7/23.0(7.8)	50.2/51.0 (12.1)	0.2/0.01/0.2
Ice	22.6/22.0 (9.6)	23.4/23.0 (4.9)	53.9/53.0 (10.0)	0.03/0.02/0.6
Alcohol	28.8/27.0 (11.6)	22.8/23.0 (5.5)	48.3/50.0 (12.3)	0.5/0.06/0.1

The OE and rubber pillow values increased about area (T0 460.4±205.4; strobe 895.7±333.7), length (T0 508.8±131.1, strobe 846.2±230.4) and reduction of L/A (T0 1.2±0.4, strobe 1.0±0.2) for the stroboscopic effect (p<0.01); a reduction in length (T0 508.8±131.1, chair 836.8±104.7) and a slight increase in an area (p<0.01), but not for the use of the chair was observed (p >0.01); an increase in area (T0 460.4±205.4, ice 604.0±338.7) with decrease in length (T0 508.8±131.1, ice 464.6±140.8) and L/A (T0 1.2±0.4; ice 0.9±0.4) for the use of ice (p<0.01); an increase in area (T0 460.4±205.4, alcohol 690.9±468.8) and reduction of L/A (T0 1.2±0.4; alcohol 0.8±0.3) for the use of alcohol was also recorded (p<0.01) (Table 4).

Table 4. Stabilometric data with rubber cushion and open eyes

Test	Average/Median (SD)			p (Area, Length, L/A ratio)
	Area (A)	Length (L)	L/A ratio	
T0	460.4/388.0 (205.4)	508.8/467.0 (131.1)	1.2/1.2 (0.4)	
Strobo	895.7/849.0 (333.7)	846.2/819.0 (230.4)	1.0/1.0 (0.2)	<0.01/<0.01/<0.01
Swivel chair	463.9/408.0 (192.5)	436.8/409.0 (104.7)	1.1/1.0 (0.4)	0.9/<0.01/0.02
Ice	604.0/480.0 (338.7)	464.6/421.0 (140.8)	0.9/1.0 (0.4)	<0.01/0.02/<0.01
Alcohol	690.9/556.0 (468.8)	474.4/448.0 (140.4)	0.8/0.8 (0.3)	<0.01/0.06/<0.01

Table 5 completes the previous table in CE and rubber pillow conditions. The results showed a variation for the swivel chair effects (p<0.01) with modest reduction of the area (T0 2416.4±1325.4, chair 1853.9±692.6) and length (T0 1419.1±448.7, chair 1190.2±340.1). Ice effect showed a reduction exclusively for the length (T0 1419.1±448.7; ice 1152±283.6) (p<0.01). The alcohol effect showed a reduction in the value L/A (T0 0.7±0.2; 0.5±0.2 alcohol) (p<0.01) (Table 5).

Table 5. Stabilometric data with rubber cushion and closes eyes

Test	Average/Median (SD)			p (Area, Length, L/A ratio)
	Area (A)	Length (L)	L/A ratio	
T0	2416.4/2198.5 (1325.4)	1419.1/1365.5 (448.7)	0.7/0.6 (0.2)	
Strobo	NE	NE	NE	
Swivel chair	1853.9/1665.0 (692.6)	1190.2/135.5 (340.1)	0.7/0.7 (0.2)	<0.01/<0.01/0.8
Ice	2007,7/1860.0 (754.4)	1152.4/1154.0 (283.6)	0.6/0.6 (0.1)	0.07/<0.01/0.07
Alcohol	3162.3/2827.0 (1848.7)	1320.8/1203.0 (389.8)	0.5/0.5 (0.2)	0.02/0.2/<0.01

NE, Not evaluable

DISCUSSION

The study evaluated the effects of different altering agents on postural control.

The results of stroboscopic light indicate an increase in the length not associated with an increase of the area, and an L/A ratio increased. Several studies have shown, through visual stimuli in motion, namely oscillating rooms or provocation due to movies projected on the visual field, of saccadic or tracking of eye movements, that the movement of the visual scene induces adaptive postural reactions, measured on the platform. However, in daily life the visual scene is not moving and can be a spatial reference (16,17). The data obtained in our study indicate that the holding of the upright static position was not altered in amplitude of the area, which remains equal to the reference T0. However, the speed or the length of the path executed would be increased and consequently the value L/A increases. These findings indicate a greater use of proprioception confirmed by reading the status-kinesigram as an increase in the density of the graph (10,12). The ToB shows that this disturbance greatly reduces the visual eso-input, compensated in proportion by other systems (vestibular and foot tactile) (9).

Data analysis of rotation on the swivel chair did not show any significant change in area and length values, but showed a very high standard deviation, index of extreme variability of results among the participants. The use of the chair with closed eyes has the purpose to alter the vestibule, stressing the vestibulo-spinal reflex (13). Horak et al. (13), in a clinical review in pathological subjects before and after rehabilitation, showed that subjects with vestibular alterations were able to maintain a stable upright static position with open eyes. In contrast, a great vestibular compensation does not appear beneficial if there are problems in the vestibular-ocular reflex. In our group of healthy subjects, we found that the visual system has corrected the imbalance caused by the vestibular alteration. The high standard deviation indicates a high variability inside the group. The ToB (9) did not indicate high value changes as a percentage of eso-input despite a significant increase in the use of the vestibule. Internal variables that could reduce this value and help to explain the phenomenon (use of glasses, blind postural etc.) have not been found.

Plantar hypothermia results indicate that the increased values of area and length were not followed by an increase in the L/A ratio. Studies engaging young athletes have shown that those who practice sports at a competitive level are less susceptible to hypothermia than amateurs (14). The study groups showed an increase in the value of area (14). Our study confirms this finding because the evaluated population was nonprofessional. We can speculate that this difference is due to the development of a better postural balance control by subjects that practice competitive sports. However, this hypothesis needs to be confirmed with studies on a wider population. The simultaneous increase of the length which confirms the value of L/A compared to T0 has to be emphasized. The ToB does not show the sensitization of neurosensory circuits by a particular eso-input (9).

Alcohol administration test showed similar results to the hypothermia test with an increase in the standard deviation as a wide diversity of participants' response. The alcoholic dose conditions the physical and mental state with a reduction of inhibition at blood concentrations over 0.02%. Only in the next stage, with the increase of the level of ethanol in blood, it is possible to reveal a beginning of impairment of posture and balance (>0.05% slow reactions; >0.1% reduced motor coordination; >0.2% severe reduction of balance) (15). The interesting finding which has emerged from the study is a clear reduction of postural control with OE than that of CE that is the opposite of what we would expect in normal conditions. This phenomenon has been detected by the group of Palm through the use of a dynamic platform, in which it was concluded that even small amounts of alcohol in the blood induce negative effects on the use of the visual system in the maintenance of posture rather than on the vestibular or proprioceptive system (15). Moreover, our data on the use of alcohol showed a high standard deviation, indicating a high variability in postural response in static station, and appears even if the participant fasted. This finding has led to the conclusion that the increase of alcohol levels in blood reduces the control that the view has in maintaining the balance. The Test of Balance does not show a different stimulation of eso-input in terms of percentage (9).

Rubber cushion analysis showed a constant variation of the area parameters in terms of increase in all stimulatory tests with OE. The length parameters appear uniformly decreased and the L/A ratio declined, especially in trials of plantar hypothermia and alcoholic administration. These results confirmed the hypothesis that the instability of the plantar support surface, in terms of drop in proprioceptive plantar component, caused greater amplitude of oscillations with a slow recovery of posture. Careful analysis of data with OE without rubber cushion, in terms of area and length, revealed a change in the control of posture for all administered stimulations. In particular, there has been an increase in both the length and the area values in plantar hypothermia and alcoholic administration tests. The cushion test has shown similar values to the alcohol test, thus confirming the study of Palm, carried out on a dynamic platform (15). Evaluation with the same parameters of rubber cushion tests with OE has reported an increase of the area especially for the hypothermia and alcohol tests. This seems to suggest a new strategy implemented by the neuronal system. The "floating sensation" of the rubber has "awakened" the voluntary control to cope with a "new" and destabilizing surface of the soil.

In conclusion, in literature there are no studies which have assessed on the same subjects the diversity of response of neurosensory adaptation as a result of different stimuli. The first hypothesis of the present study (each single perturbing external agent could significantly modify postural control) has not been fully confirmed by ToB analysis (altering effects only for the strobe light and the swivel chair tests). As for the second hypothesis (there are no differences when comparing the different altering sources), it is clear that different tests do not trigger the deficit of postural control in the same way and with the same features. Strobe light input and rotation of the body in space have influenced respectively the view (decrease compared to the vestibule and touch) and the vestibule (increase compared to view and touch), while plantar hypothermia and alcohol have increased the oscillation area. Therefore, a particularly low temperature or stressful setting against neurosensory input that control posture such as in nightclubs (psychedelic lights and intake of alcoholic beverages) could significantly alter the maintenance of postural stability. This study should certainly be conducted on a larger population and increasing time of the single altering stimuli in order to assess the effects that some real-world conditions may have on the nervous system.

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TRANSPARENCY DECLARATION

Conflicts of interest: None to declare

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