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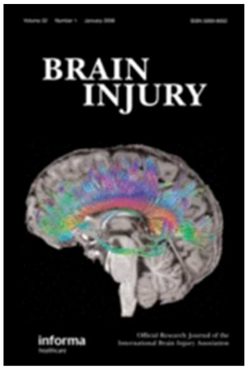

Progression of posturographic findings after acquired brain injury: A validation study with the NedSVE-IBV system

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Abstract

Objective: To study the characteristics of balance performance in a sample of patients with increasing postural instability after acquired brain injury (ABI), and to establish the clinical utility of a new computerized posturographic system (NedSVE/IBV). Methods: We included 108 patients with ABI divided into five groups from minimal to severe postural impairment. All patients were assessed with the NedSVE/IBV system and with traditional balance measures. Posturographic analyses included the modified clinical test of sensory interaction on balance, the limits of stability, and the weight-shifting test. Sensitivity to detect changes and reproducibility were evaluated in sixty-three patients who were followed-up for 6 months and in 20 patients who were evaluated on two separate occasions during the same week, respectively. Results: Our patients showed reduced stability limits, abnormal postural responses, and an increased reliance on visual input with differences in intensity directly related to their degree of balance impairment. Posturographic study showed excellent convergent validity, reproducibility, and sensitivity to detect changes. Conclusion: Our data suggests that regardless of the intensity of postural instability, there is a common mechanism of sensory processing to maintain balance after ABI. The NedSVE-IBV system is a valid tool to quantify balance after ABI.

Introduction

Balance disorders are amongst the most frequent complaints of patients who have sustained an acquired brain injury (ABI) [1, 2]. The recovery of balance is a major goal for rehabilitation interventions because balance and postural control are crucial to carry out most daily activities [3-5]. The assessment and monitoring of these deficits has been performed with either subjective clinical scales or laboratory instrumentation, such as force-platform balance measurement devices, known as computerized posturography testing (CPT) [6, 7]. Clinical balance scales have practical advantages, including their ease of administration and their low cost, but they usually do not provide information about the sensorial integration required to maintain balance, and they can be biased sometimes by subjective judgment. Moreover, in patients with a high level of mobility, some of these scales may lack sufficient clinical sensitivity to detect minor but significant balance problems [7]. Conversely, laboratory measurements, although more time consuming, can assess balance control with greater sensitivity and objectivity than observational methods, and can quantify postural reactions in situations of altered sensorial or environmental conditions [8].

Postural control requires the collaborative function of a complex system under feedback regulation. This system includes the central processing of afferent (sensory) inputs to provide adequate balance responses through an efferent (motor) system. Interestingly, each of these systems may be affected after ABI [4]. Alterations in one or both of these systems, may generate abnormalities on weight bearing and sway characteristics, which can be detected by CPT through the analysis of the position and movement characteristics of the center-of-pressure (COP). In addition, CPT may also analyze the functional contributions of the sensory information (vestibular, visual and somatosensory inputs), which are necessary for balance modulation [8]. Current CPT equipments can also assess the ability of the automatic motor system to quickly recover following an unexpected external perturbation with some devices even offering interactive, functional training exercises tailored to meet individual patient needs according to the deficits identified during assessment (see [9] for a review).

Most of the posturographic studies conducted to date in patients with ABI have shown a particular sensitivity to detecting balance disorders, which can be subtle enough to be missed on routine clinical examination [10, 11]. The emergence of more technologically advanced systems has corroborated these data and has also demonstrated the patients' overreliance on visual compensatory strategies to maintain their balance [12-14]. Additionally, according to these studies, when standing quiet on a posturographic platform, persons with ABI tend to sway more in the sagittal and lateral directions and are slower in weight-shifting than controls. Unfortunately, most of these studies are based on cross-sectional analysis of small selected samples assessed at a fixed time during the recovery process, so a more global description of these problems, especially in large samples with different intensities of postural imbalance, is lacking.

This study aims to provide information about posturographic findings, including sensory inputs, limits of stability (LOS) and rhythmic weight shift (RWS), in a consecutive sample of ABI patients. In an effort to make a wide description of CPT findings in this population, we present data from patients with different levels of postural imbalance. Our study also seeks to validate a new posturographic system (NedSVE/IBV) as a valid and reliable tool for studying and monitoring these difficulties in this population. Our aim is that studying the relationship between clinical and posturographic data, a better understanding of balance problems in these patients could guide future rehabilitative interventions.

Patients and Methods

Patients

From August 2004 to December 2008, all patients with ABI entering a specific rehabilitation program in a large metropolitan hospital, who were able to stand unassisted for 30 seconds, were candidates to participate in the study. We excluded all patients who were in post-traumatic amnesia after a traumatic brain injury (Galveston

Orientation and Amnesia Test score <75[15]), or those who after a non-traumatic brain injury were not judged to be cognitively capable of understanding instructions for testing (Mini Mental State Examination score <24[16]). Patients with uncorrected visual problems, altered somatosensory perception upon neurological examination or severe arthritic or orthopedic conditions affecting the ankles, knees, hips or back, were also excluded. Twelve patients who fulfilled the inclusion criteria refused to participate, and data from five patients were missing or incomplete. The final sample consisted of 108 patients, 33 (30.6%) women and 75 men (69.4%) with a mean age of 41.2 years (SD = 15.8 years). Chronicity, calculated as the interval in days from date of injury to date of assessment, was 187.8 days (SD = 156.8 days). Fifty-three patients of the sample have a right hemiparesis (49%), forty-three a left hemiparesis (39.8%), six patients (5.5%) have a bilateral motor deficit and there was no apparent motor deficit on clinical examination in six patients (5.5%). Etiology of ABI included an ischemic or hemorragic stroke (n = 50), severe traumatic brain injury (n = 45), intracranial neoplasm (n = 5) anoxic encephalopathy (n = 1), and others (n = 7).

Clinical and posturographic data were analyzed based on data from 210 assessments, including the initial evaluation of the 108 patients and clinical and posturographic data of 63 and 39 patients who were followed-up during six (186.3±49.2 days) and twelve months (375.4±78.2 days), respectively. As previously published [17, 18], each patient at each assessment time was classified into one of five groups according to their score on the Berg Balance Scale (BBS), which is based on increasing balance impairment and risk of falls [19]: Group I) BBS range of <39 (23 assessments); Group II) BBS range between 40-44 (24 assessments); Group III) BBS range between 45-49 (32 assessments); Group IV) BBS between 50-54 (61 assessments); and Group V) BBS scores of 55 or 56 (70 assessments).

Assessment protocol

All patients underwent a clinical and neurological examination at inclusion which included a wide battery of balance measures (Berg Balance Scale [19] , Tinetti Balance Assessment [18]), gait scales (Tinetti Gait Assessment [20], Functional Ambulation Categories [21], Hauser Ambulation Index [22]), and global mobility measures (Clinical Outcome Variable Scale [23], Internacional Cooperative Ataxia Rating Scale [24], Rivermead Mobility Index [25]). During the same week, all subjects were informed about the testing procedure and were tested barefoot on a single force CPT (NedSVE/IBV). This force plate consists of a board (600x370mm) with four sensors (Dinascan600-IBV) composed of eight extensiometric gauges each (four to detect vertical forces with a range of 4500N and four to detect horizontal forces with a range of ±750N) [26, 27].

The NedSVE/IBV provides objective measures of the basic components involved in balance control, including a computerized version of the modified clinical test of sensory interaction on balance (mCTSIB), the limits of stability (LOS), and the rhythmic weight-shifting tests (RWS) [26, 27]. The mCTSIB consisted of three 30-second Romberg trials under four sensory conditions: 1) eyes open, firm surface (REO), where all sensory systems are available for maintaining balance; 2) eyes closed, firm surface (REC), where balance relies on somatosensory and vestibular systems; 3) eyes open, unstable (foam) surface (RFEO), where the patients must use vision and the vestibular system to balance; and 4) eyes closed, unstable (foam) surface (RFEC), where the patients must rely primarily on the vestibular inputs to balance. Each Romberg score was calculated based on the average of the maximum mediolateral and anteroposterior displacements (mm). The analysis of all these Romberg conditions provides some insight into whether each of the sensory systems available for balance is being used effectively [28]. Failure to maintain balance in condition two (REC) indicates that the patient is visually dependent (impairment of the dominant somatosensory input), while failure to maintain balance in conditions 3 and 4 (RFEO and RFEC, respectively) indicates that the visual and/or vestibular system is not being used to maintain balance.

The LOS task involves shifting the weight to eight target positions arranged in an ellipse on the monitor screen, the perimeter of which corresponds to 100% of the theoretical limits of stability. In this procedure, subjects were required to shift their center of gravity to follow a ball-shaped cursor to each target as it was highlighted, and to remain at that target position for eight seconds before returning to the center of the ellipse. Targets were highlighted in order, and each target was selected only once. A global score for each of the eight targets were calculated considering, maximum excursion (55%), directional control (25%), time to reach the target (10%), reaction time (5%) and accuracy (5%). An average LOS score was determined across targets.

The weight-shifting tests quantifies the patient's ability to rhythmically move their center of gravity from left to right (RWS-ML) and forward to backward (RWS-AP) between two targets located at 60% of the subject’s stability limits, at three distinct speeds: slow (3.5 second peak to peak pacing), medium (2.5 second pacing), and fast (1.5 second pacing). A mean global score for each RWS was calculated considering the amount of movement in the intended direction (70%) and the amount of extraneous perpendicular movement (30%).

A composite equilibrium score (Global-SVE) including information from sensorial analysis (50%), LOS (30%) and RWS (20%) was calculated that describes the overall level of performance during CPT. All indexes are shown in percentage (%), so that differences from 100% reflect discrepancies from an age- and height-matched normative data provided by the system, and that the lower the value, the greater the degree of impairment. According to the specifications of the system, abnormal scores included discrepancies of 5% from the values of the normative group for the REO, REC, RFEO; of 10% for Global-SVE; and of 15% for RFEC, LOS, and RWS.

Statistical analysis

Descriptive statistics were used to analyze clinical and posturographic results in the total sample and in the five different groups. The floor and ceiling effects were calculated as the percentage of the sample scoring the minimum or maximum possible scores, respectively. Ceiling and floor effects of 20% or greater were considered significant. [29]. The strength of the relationships among the posturographic analysis and clinical data were examined using the Spearman rank-order correlations. Responsiveness was addressed from data of those 63 patients who were followed-up during 6 months, using the Standardized Response Mean (SRM) and the Standardized Effect Size (SES) [30]. The standardized response mean (SRM) was computed as the ratio of the mean change in scores divided by the standard deviation of the change scores. Cohen’s criteria were used to evaluate the calculated effect size; 0.2 to .49 is considered small, 0.5 to 0.8 is moderate, and 0.8 or higher is large [31]. Test-retest reliability was evaluated with posturographic data from twenty consecutive patients who were assessed twice in the same week (mean: 5±2.9 days, with a range of 2-7 days). We used two statistical indices to investigate the test-retest reliability of the balance measures over the one-week period. First, paired *t* tests were performed to examine the changes for statistical significance. Second, a 1-way random effects model intraclass correlation coefficient (ICC) was used to summarize the strength of the test-retest reliability. Values 0.8 or higher indicate high reliability, and values in the range of 0.6 to 0.8 represent moderate reliability [30]. All statistical analyses were carried out using SPSS 13.0 for Mac. The level of significance was set at *p* less than .05. Data are presented as means and standard deviations (mean ± SD) unless otherwise stated.

Results

Descriptive analysis

The results from posturographic and clinical data are listed on table 1.

Insert table 1 about here

No ceiling effect was detected when analyzing posturographic data. Conversely, the scores on the clinical measures were clustered at the top end of the scales, especially when analyzing Tinetti Gait Assessment, Tinetti Balance Assessment, Functional Ambulation Categories and Rivermead Mobility Index, resulting in ceiling effects of 53%, 41.6%, 38.3% and 34.1%, respectively. The Hauser Ambulation Index and the Berg Balance Scale also exhibited a ceiling effect with 28.5% and 27% of participants scoring 0 (independent gait) and 56 (normal balance), respectively. Only the COVS showed a ceiling effect below the percentage considered significant (16.8%). Regarding floor effects, the intergroup analysis showed that none of the 23 patients assessed in Group I were able to perform the RFEC. Nine of these patients also failed to finish the RFEO. Two of these nine patients scored on the lower range for inclusion in the study, and the remaining seven had a significant ataxic component. Considering the Romberg cutoff score of 95%, eleven patients (47.8%) scored under normality on the REO, seventeen (73.9%) on the REC and sixteen (69.6%) on the RFEO (figure 1).

A similar sensorial pattern persisted in patients from Group II and Group III, with a total of 20 patients (83.3%) and 22 patients (68.8%) who could not performed RFEC, respectively. One patient (4.2%) in Group II and three patients (9.4%) in Group III scored below 95% on the REO. These percentages increased to 37.5% in Group II and 25% in Group III when analyzing RFEO and to 50% and 37.5% when analyzing REC in the same groups (figure 1).

The percentage of patients unable to perform RFEC decreased to 37.7% and 5.7% in Group IV and V, respectively. Characteristically, 44.3% of patients in Group V reached the maximum scores of 100 in RFEC. All patients from these groups scored above 95% on REO. Twelve patients (19.7%) from Group IV and six (18.6%) from Group V showed abnormal values on both the REC and the RFEO (figure 1).

Insert figure 1 about here

As could be expected, both the LOS and the RWS showed increasing values from Group I to V. Mean scores on LOS were clearly deficient in Group I, II and III, showed borderline values in Groups IV, and were within normal values in Group V. The LOS of hemiparetic patients showed a predominant reduction on the paretic side. Regarding RWS mean scores, both movement strategies were clearly deficient in Group I, showed borderline values in Groups II and III, and were within normal values in Group IV and V. The mean anteroposterior strategy tended to be slightly more affected in all groups. The percentage of patients with abnormal LOS and RWS scores are shown on figure 2.

Insert figure 2 about here

Convergent validity

Table 2 shows the matrix of correlations between clinical scales and posturographic data. The NedSVE/IBV composite equilibrium score (Global-SVE) showed a strong correlation not only with clinical balance scales, such as the Berg Balance Scale ($r = 0.83$ $p < 0.01$) but also with other global mobility scales, like the Hauser Ambulation Index ($r = 0.72$, $p < 0.01$) or the Rivermead Mobility Index ($r = 0.7$, $p < 0.01$) reflecting the importance of balance on global functional mobility. The intensity of the correlation was lower when more specific posturographic data, such as LOS and RWS, were included in the correlation matrix. However, the correlation was significant in all cases.

Insert table 2 about here

Regarding etiology, the values of the correlation matrix showed little differences between the two main patient groups in our sample (r = 0.82, p <0.01, for Berg Balance Scale and Global-SVE correlation in patients who had sustained a stroke, and r = 0.86, p <0.01, in patients who had sustained a traumatic brain injury).

Responsiveness

Table 3 compares the responsiveness among the balance measures and the posturographic data. The analysis of posturographic data showed that global scores were more sensitive detecting changes across time (Global-SVE: ES = 0.7 and ERM = 0.1) compared to more specific posturographic measures, or to those posturographic indexes with values reaching the maximum score at baseline.

Insert table 3 about here

Reproducibility

Table 4 shows the excellent reproducibility of CPT with values of test-retest reliability above 0.8 in all the CPT scores. When posturographic data from those twenty consecutive patients who were assessed twice in the same week was analyzed, none of the CPT measures showed a significant difference between the two measurements (paired *t* test, *P*>.05).

Insert table 4 about here

Discussion

Our study confirms the high prevalence of balance disorders previously described in patients who have sustained an ABI [1, 4, 11-13, 32-34]. Although the NedSVE/IBV system has been previously used in healthy subjects and patients with vestibular disorders, this is the first study to investigate the clinical utility of this system in ABI population [26, 35, 36]. As previously reported, a high percentage of our sample present balance abnormalities, despite some participants having reached the ceiling of some of the scales commonly used in clinical practice. According to CPT data, our patients have reduced stability limits (mainly in the paretic side of the body), show abnormalities on movement strategies, have an increased reliance on visual input and perform worse on conditions of altered somatosensory information and visual deprivation, suggesting a deficit in managing vestibular information. This profile seems to be reproduced, in different intensities, in all ABI patients. The differences in intensity are directly related to the degree of balance impairment detected with clinical measures.

Our results agree with previously published studies that used smaller samples of subjects with ABI who had milder symptoms of imbalance and were assessed at a fixed time during the recovery process [10-12, 14, 37]. Decreased multisensory integration, with excessive reliance on visual information and consequent poor balance control, has been demonstrated during the acute and chronic stages after a stroke [12, 13]. Cross-sectional studies have shown that stroke patients show abnormal visuovestibular integration preferentially at acute and subacute stages [38]. When analyzing prospective data, it seems that balance recovery after a first-time stroke is characterized by a reduction in postural sway and instability as well as by a reduction in visual dependency, particularly with regard to frontal plane balance [37].

Balance evaluation at a set time after injury may increase the confounding influence of evaluation results with those of injury severity. To avoid such confusion, patients can be assessed at a particular clinical point along the recovery process. Our results, including consecutive posturographic data from ABI patients with different levels of postural imbalance, complement these previous investigations focusing on posturographic changes occurring across time. In this sense, the high number of posturographic studies reported here provides an overview of how ABI patients manage to achieve postural stability after their first attempt to stand unassisted. Our data confirm the deficit of these patients in managing vestibular afferents and the clear dominance of the visual afferents across the process of regaining postural balance [12-14, 37]. This also suggests that, regardless of the intensity of balance impairment, in these patients there is a common mechanism of sensory processing.

It is unclear what are the underlying neural deficits causing postural instability after ABI. The disruption of the corticobulbar projections to brain stem output pathways involved in vestibular control of balance has been proposed to explain balance deficits after stroke [39]. Other possibilities, including pure vestibular or cerebellar syndromes, deficits in cognitive processing speed to readjust balance, and spatiotemporal disruption of postural responses due to diffuse axonal injury after traumatic injuries, have also been proposed [4, 28]. Similarly, it is not clear whether the visual dependence of these patients reflect an impaired integration of multisensory information, or just a compensatory strategy due to the loss or distortion of other sensory input [12, 13]. Future longitudinal studies could help to elucidate if the cross-sectional data reported here, especially those regarding sensory organization, are a direct consequence of brain injury or are the consequence of compensatory or adaptive plastic changes over time.

Our patients also showed a clear reduction on their limits of stability, especially on the affected side, reaching only values close to normality in patients scoring above 45 in the Berg Balance Scale. This preferential reduction on the paretic side has also been described in other samples of hemiparetic patients in previous studies [40]. Additionally, as previously reported, our sample also showed an overall reduction on the two motor responses for postural corrections that need to be triggered rapidly to prevent a fall. These strategies are usually used for keeping the trunk in a vertical position during small perturbations while standing (ankle strategy) or for faster and larger center of mass movements (hip strategy). Deficits in managing sensorial information may be partially responsible for these difficulties because somatosensory loss results in an increased hip strategy, whereas vestibular loss results in normal ankle strategy, but lack of hip strategy [41]. In agreement with our results, it is well-known that patients with stroke predominantly use the hip strategy (RWS-ML) to maintain the same base of support, which is maladaptative and counterproductive [42].

Our results may have important implications for the future design and assessment of balance-rehabilitation interventions in patients with ABI. Rehabilitation programs of postural control for these patients should take into account the possible impairment of sensory organization and should include exercises to be performed under conditions of sensory input deprivation and sensory conflict. Additionally, postural rehabilitation under these conditions may be able to redirect patients' efforts and reorient their postural responses from hip to a more effective ankle strategy, especially considering that increasing the anteroposterior rhythmic weight and shift control is associated with a decreased risk of falls [42]. Finally, the improvement in the symmetry of weight distribution is considered a primary therapeutic goal because it has been associated with better and safer performance during gait and has a relevant influence on functional independence [4, 5, 33].

Regarding other psychometric properties of the NedSVE/IBV system, a recent study using this device in a sample of 14 healthy subjects and 16 patients suffering from balance-related complaints has shown an excellent validity and reliability [35]. Our data extends those results to the ABI population and are in agreement with previous CPT studies which showed an adequate correlation of posturographic data and clinical measures of balance [43, 44]. At the same time, some of the NedSVE/IBV measures seem to have enough sensitivity to detect changes over time, which can make this system a useful tool to monitor progress.

Some limitations of our study should be considered; first while most previous studies have considered etiology or chronicity as inclusion criteria, our data are based on the level of balance impairment at admission. Second, although the overall sample seems to show similar posturographic results, we cannot rule out individual differences that may reflect different pathophysiological mechanisms resulting from the initial etiology that caused the brain damage. Additionally, our data are derived from a cross-sectional analysis. Further longitudinal studies analyzing the behavior of different subgroups of the sample provided here may help to confirm our results. Finally, sensorial analysis and data regarding weight shift should be interpreted cautiously because our assessment was performed in a single fixed platform and sensorial analysis were extracted from the mCTSIB. In this sense, the four conditions of the mCTSIB have been shown to correspond reasonably closely to the various conditions of the SOT of dynamic posturography with the added advantage of a cheaper price [45]. Additionally, previous studies have demonstrated the usefulness of the mCTSIB, especially the foam condition, as a measure of vestibular dysfunction [45, 46].

Conclusion

In conclusion, our data suggests that regardless of the intensity of postural instability, there is a common mechanism of sensory processing to maintain balance after ABI. Our results demonstrate the validity of the NedSVE/IBV system for detecting and quantifying postural instability in a sample of patients with ABI. The quantitative CPT measures appear well suited to providing information on even subtle balance impairment, with excellent reliability. We recommend the use of these systems in rehabilitation settings because CPT can provide quantitative data to track changes over time and/or assess the efficacy of treatment interventions while avoiding the ceiling effect of conventional clinical balance scales.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Table 1. Posturographic and clinical values. Data are mean±standar deviation

	Group I (n=23)	Group II (n=24)	Group III (n=32)	Group IV (n=61)	Group V (n=70)
Global-SVE	63,1±8,2	75,7±6,7	78,7±7,0	85,6±7,2	92,4±4,2
Romberg Eyes Open	93,3 ±6,9	97,6 ±2,5	98,1 ±3,3	98,57 ±1,9	98,9 ±2,1
Romberg Eyes Closed	88,0 ±9,8	93,1 ±6,3	94,2 ±5,9	96,7 ±3,7	97,4 ±3,5
Romerg-foam Eyes Open	57,0 ±47	96,0 ±4,5	96,4 ±5,6	97,1 ±4,2	98,3 ±3,3
Romberg-foam Eyes Closed	-	16,7 ±38,1	30 ±45,1	57,7 ±46	88,2 ±23,4
Limits of Stability	72,1±10	76,5±12,6	80,6±8,8	85,5±6,8	89,4±5,7
Rhytnmic Weight Shift-ML	78,7±12,3	87,2±10,8	86,4±11,8	90,7±9,7	94,6±8,8
Rhytnmic Weight Shift -AP	78,0±15	86,9±12,9	84,9±14,3	87,2±11,7	91,7±8,1
Berg Balance scale	36,2±2,5	42,6±1,4	47,2±1,6	51,9±1,5	55,8±0,4
Hauser Ambulation Index	5,1±1,6	3,7±1,4	3,1±1,1	1,9±1,2	0,4±0,7
Rivermead Mobility Index	7,1±1,5	9,3±2,3	10,9±2	13,3±1,6	14,8±0,5
COVS	66,9±9,5	71,3±7,4	75,9±6,9	84,2±5,7	88,6±4,8
Tinetti-Balance Scale	11,2±2,5	13,8±1,6	14,6±1,3	15,5±0,9	15,7±1,2
Tinetti- Gait Scale	7,3±2,1	8,6±2,3	9,7±1,8	10,9±1,3	11,7±0,6
FAC	2,6±1,1	3,4±0,6	3,9±0,7	4,4±0,7	4,8±0,6
ICARS	14,8±7,8	11,4±6,6	10,0±8	6,2±4,2	2,8±3,5

Abbreviations: COVS, Clinical Outcome Variable Scale; FAC, Functional Ambulation Categories; ICARS, International Cooperative Ataxia Rating Scale .

Table 2: Correlation among balance measures used in this study

	Global-SVE	LOS	RWS-ML	RWS-AP
Berg Balance Scale	,83**	,61**	,45**	,33**
Hauser Ambulation Index	-,72**	-,51**	-,39**	-,29**
Rivermead Mobility Scale	,7**	,44**	,33**	,24**
Tinetti Balance	,67**	,54**	,504**	,41**
Tinetti Gait	,64**	,45**	,31**	,23**
Functional Ambulation Categories	,64**	,51**	,33**	,22**
ICARS	-,61**	-,42**	-,41**	-,35**
Clinical Outcome Variable Scale	,6**	,43**	,28**	,15**

Abbreviations: ICARS, International Cooperative Ataxia Rating Scale; LOS, Limits of Stability; RWS-ML and AP, Rythm Weight Shift medio-lateral and anteroposterior.

** p<0.01

Table 3. Comparison of the Responsiveness among balance measures used in this study

	1st Evaluation (mean±SD)	2nd Evaluation (mean±SD)	Mean Change Score	SES	SRM
Global-SVE	78,4 ±11,8	86,7 ±9	8,5± 8,2	0,7	1
Romberg Eyes Open	96,7 ±5,1	98,8 ±1,7	2,1 ±4,7	0,4	0,4
Romberg Eyes Closed	93,1 ±7,6	97,3 ±3,5	4,1 ±6	0,5	0.7
Romberg-foam Eyes Open	91 ±21,6	96,3 ±13,1	5,3 ±16,9	0,2	0,3
Romberg-foam Eyes Closed	40,1± 46,6	61 ±45,6	20,8 ±37,7	0,4	0,5
Limits of Stability	78,5 ±11,3	86,6± 7	8,1± 7,9	0,7	1
Rythmic Weight Shift-ML	86,1 ±12,4	93,8 ±8,4	7,6 ±11,5	0,6	0,7
Rythmic Weight Shift-AP	83,5 ±13,8	88,9 ±11,2	5,4 ±11	0,4	0,5
Berg Balance Scale	46,3± 7,3	52± 4,5	5,7 ± 6	0,8	0,9
Hauser Ambualtion Index	2,8 ±1,9	1,5± 1,5	1,3 ±1,6	0,7	0,8
Rivermead Mobility Index	11 ±3,2	13,2± 2,2	2,2 ±2,6	0,7	0,8
COVS	76,5± 10,8	84,8 ±6,8	8,2 ±9,4	0,8	0,9
ICARS	9,3 ±6,3	5,3 ±5	4 ±5,5	0,6	0,7
FAC	3,6 ±1,1	4,5 ±0,7	0,8± 1,1	0,8	0,7
Tinetti Balance	14 ±2,4	15,5 ±0,9	1,4 ±2,1	0,6	0,7
Tinetti Gait	9,6 ±2,1	11 ±1,5	1,4 ±1,6	0,7	0,9

Abbreviations: COVS, Clinical Outcome Variable Scale; FAC, Functional Ambulation Categories; ICARS, International Cooperative Ataxia Rating Scale; SES, Standardized Effect Size; SRM, Standardized Reponse Mean.

Table 4: Test-retest reliability of posturographic data(n = 20). Range: 5 ± 2.9 days

	1st Assessment	2nd Assessment	Pearson	ICC
Global-SVE	82 ± 12,7	82,7 ± 12,3	1**	1**
Limits of Stability	82,3 ± 10,2	83,5 ± 10,1	1**	0,9**
Rythmic Weight Shift-ML	91,1 ± 9	92,1 ± 8,6	1**	0,8**
Rythmic Weight Shift-AP	88,7 ± 9,2	89,5 ± 8,8	1**	0,8**
Romberg Eyes Open	98,2 ± 3,1	98,3 ± 3	,9**	0,9**
Romberg Eyes Closed	95,8 ± 5,2	96 ± 4,9	,9*	0,9**
Romberg-Foam Eyes Open	92,8 ± 22,1	92,8 ± 22,2	1**	1**
Romberg-foam Eyes Closed	57 ± 48,2	56,6 ± 47,9	1**	1**

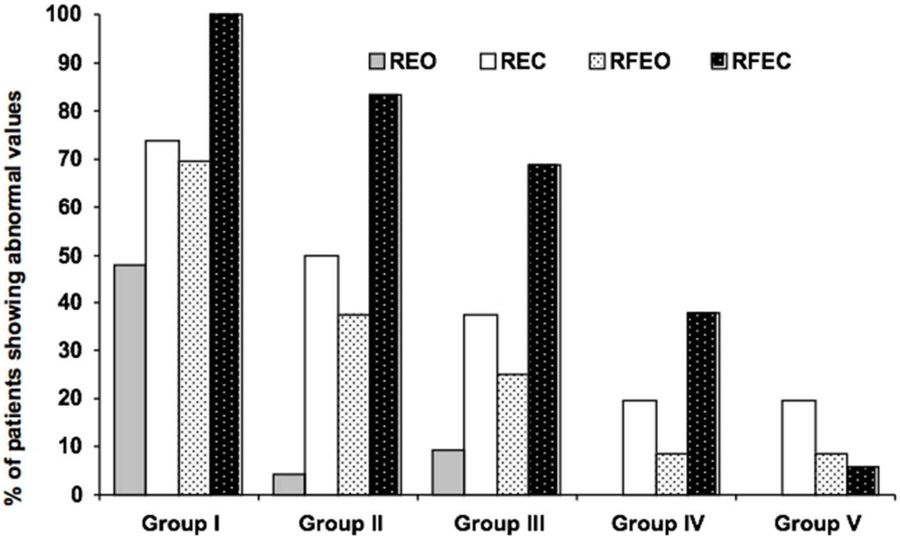

Figure 1- Percentage of patients on each group of postural impairment showing abnormal values (below cutoff) on the four conditions of the modified clinical test of sensory interaction on balance. REO: eyes open, firm surface; REC: eyes closed, firm surface; RFE: eyes open, unstable (foam) surface; RFEC: eyes closed, unstable (foam) surface.

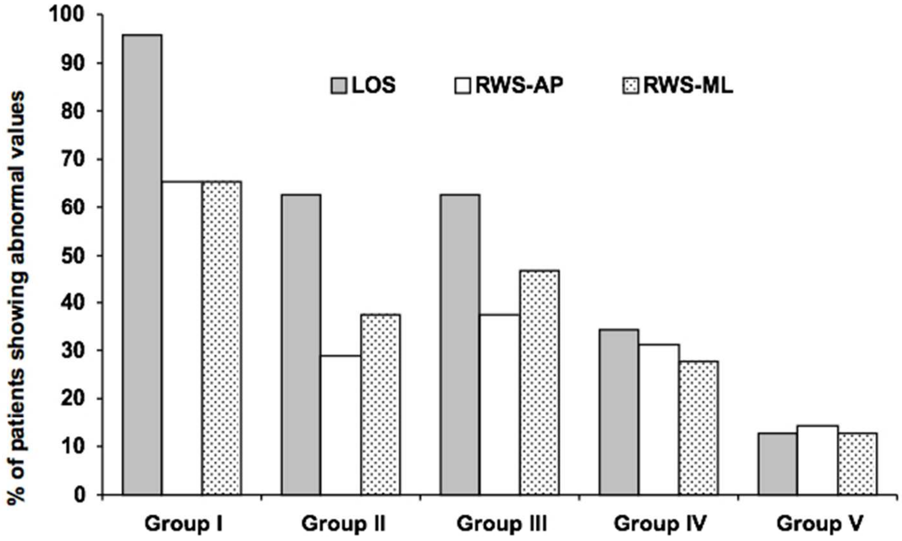

Figure 2- Percentage of patients on each group of postural impairment showing abnormal values (below cutoff) on Limits of stability (LOS), medio-lateral Rythm Weight (RWS-ML) and anteroposterior Rythm Weight Shift (RWS-AP)

Figure captions

Figure 1- Percentage of patients on each group of postural impairment showing abnormal values (below cutoff) on the four conditions of the modified Clinical Test of Sensory Interaction on balance. REO: eyes open, firm surface; REC: eyes closed, firm surface; RFE: eyes open, unstable (foam) surface; RFEC: eyes closed, unstable (foam) surface.

Figure 2- Percentage of patients on each group of postural impairment showing abnormal values (below cutoff) on Limits of Stability (LOS), medio-lateral Rythm Weight (RWS-ML) and anteroposterior Rythm Weight Shift (RWS-AP)