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Computerized posturography is more sensitive than clinical Romberg Test in detecting postural control impairment in minimally impaired Multiple Sclerosis patients

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ABSTRACT

Balance impairment, frequent in Multiple Sclerosis patients (MS), is difficult to detect promptly with routine clinical examination. Computerized platforms can measure subtle deficit but, given the complexity of postural system, multiple tests should be adopted. To evaluate whether platform was more sensitive than Romberg Test (RT) in detecting balance abnormalities, we 1) chose a battery of posturographic tests, 2) collected normative data from 58 healthy subjects 3) applied the tests to Clinically Isolated Syndrome (n=42) and minimally impaired MS (n=76). Subjects underwent 3 trials of quiet standing with eyes open and closed (modified Clinical Test of Sensory Interaction on Balance, mCTSIB) and 4 trials of voluntary anterior and lateral maximal leaning on right and left sides (Limits of Stability, LOS), giving 10 postural indexes. For every subject, the best trials were selected for subsequent analysis. Normative values were established in a range from 1st to 99th percentile, defining balance impairment by the presence of at least 2 indexes out of range. Even adopting the above mentioned strict definition of balance impairment, the forceplate resulted more sensitive than RT, detecting abnormalities in 25% of patients, while RT was abnormal in 7% only. In RT-negative patients with 1-year follow-up (n =67) the detection of a single abnormal index was able to predict a subsequent onset of symptomatic balance impairment. The proposed procedure is quick, easy to perform and can improve the assessment of the clinical course of MS, from a pre-clinical stage up to medium degree of disability.

1. Introduction

Balance deficits seem to represent an early hallmark in Multiple Sclerosis, (MS) (Fling et al., 2014; Martin et al., 2006) frequently poorly investigated or difficult to detect in routine clinical settings. In MS many features may impair postural control: vestibular-cerebellar lesions (Prosperini et al., 2011), reduced motor control, abnormal sequencing of muscle contraction (Ashburn and De Souza, 1988), strength and limb-loading asymmetries (Chung et al., 2008), spasticity (Sosnoff et al., 2011) and sensory impairment (Cattaneo and Jonsdottir, 2009). Therefore, a single measure could be inadequate to evaluate the overall function of postural control (Horak et al., 2009). In this regard, given the increasing interest in the prompt recognition of impairment at the early stages of the disease, the computerized stabilometric platform can be used and privileged over clinical scales, as self-administered questionnaires and functional assessment scoring tests such as Romberg Test (RT), Berg Functional Balance Scale, Balance Evaluation Systems Test. These functional assessments are easy to use and do not require expensive equipment, but produce subjective results, show ceiling effects, are usually not responsive enough to measure small progress or deterioration in a subject's ability to balance (Blum and Korner-Bitensky, 2008), especially in asymptomatic Clinical Isolated Syndrome (CIS) or MS (Karst et al., 2005) patients.

Forceplates generally compute the Centre of Pressure (COP) location under the feet, assessing balance by measuring COP sway in standing position; the Neurocom system estimates the Centre of Gravity (COG) displacement, i.e. the point of action of the total gravitational force. In upright stance, the COG is positioned at a height corresponding to 55% of the stature, in front of the medial malleolus at a distance equal to 14% of foot length (Balance Manager® Systems, 2011). This

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platform measures the changes of the angle formed by two lines: the first extending vertically from the COP and the second from the COP through the COG (Balance Manager® Systems, 2011).

In static tests the COG sway outlines the ability to process sensory systems input to maintain balance control; in dynamic testing condition, the limits of stability (LOS) defines the ability to maintain the COG within the base of support during active movements towards predefined targets requiring a maximal leaning position, allowing the assessment of motor component of postural control: poor balance causes COG sway increase in standing still position and may impair the ability to move the COG towards the LOS (Horak et al., 2009).

Researches and clinical applications of forceplates generally focus on the intervention to improve gait and balance in disabled MS and to prevent falls (Zackowski et al., 2014; Prosperini et al., 2013), but few studies have compared the sensitivity of clinical tests/scales with posturography during the early stages of MS (Prosperini et al., 2011; Ganesan et al., 2015), using different computerized tests and measures, rarely providing normative data (Kalron et al., 2011; Cattaneo et al., 2015).

Our purpose was to evaluate whether posturography were more sensitive than RT in detecting balance impairment in MS. To obtain this goal we chose a set of posturographic tests (PT), collected normative values from a group of healthy subjects and applied them to a MS population. Moreover, in a subgroup of patients with one year-follow up data available, we evaluated if basal PT were predictive of clinical detectable changes in balance function after one year.

2. Materials and methods

2.1. Subjects

Fifty-eight healthy controls (HCs) from the hospital staff, 76 Relapsing Remitting MS (RRMS) patients diagnosed according to McDonald revised criteria (Polman et al., 2011) and 42 patients with a diagnosis of Clinically Isolated Syndrome (CIS), (Miller et al., 2005) all presenting an abnormal MRI scan at baseline, referred to the Regional Centre of Multiple Sclerosis of San Luigi Gonzaga Hospital were recruited. Time from disease onset did not overcome 17 months (median) and most of the patients showed none or low disability (Table 1). Fall history was collected by retrospective recall (defining falls "an episode of unintentionally coming to rest on the ground or lower surface", (Friedman et al., 2002)): no patient reported falls. The exclusion criteria for HCs were self-reported balance disorders and vestibular disease; for patients were an Expanded Disability Status Scale (EDSS) score > 3.5, dizziness, diplopia and/or blurred vision, inability to stand upright with enlarged base of support for at least 30 s, bone and joint pathology with significant functional limitations of movements and cognitive impairment preventing the understanding of the instructions related to the tasks.

All participants gave written informed consent to the study, approved by the San Luigi Gonzaga Hospital Ethics Committee and conducted according to the Declaration of Helsinki.

Table 1
Demographic and clinical characteristics of the study population.

	Healthy Subjects (n 58)	*CIS patients (n 42)*	*MS patients (n 76)*	*p value*
F:M (% F)	37:21 (63.8%)	29:13 (69%)	*48:29 (63.15%)*	n.s[b]
Age (years)	38.5 (21–66)	34.5 (16–63)	36 (13–65)	n.s.[a]
Height (cm)	165 (140–189)	163 (146–187)	167 (147–186)	n.s.[a]
Time from disease onset (months)	/	4 (0–71)	17 (0–347)	
EDSS (score)	N/A	1.0 (0–2.0)	1.0 (0–3.5)	N/A
Pyramidal	N/A	1.0 (0–2.0)	1.0 (0–3.0)	N/A
Cerebellar	N/A	0 (0–1.0)	0 (0–1.0)	N/A
Brainstem	N/A	0 (0–1.0)	0 (0–1.0)	N/A
Sensory	N/A	0 (0–1.0)	0 (0–3.0)	N/A
Bowel and Bladder	N/A	0 (0–1.0)	0 (0–2.0)	N/A
Visual	N/A	0 (0–0)	0 (0–3.0)	N/A
Cerebral (Mental)	N/A	0 (0–0)	0 (0–1.0)	N/A
Other	N/A	0 (0–0)	0 (0–1.0)	N/A

Data are expressed as median and range.
N/A= not applicable.
[a] Mann-Whitney test.
[b] *Chi-square test.*

2.2. Methods

Subjects underwent RT, scored according to the Neurostatus system (Kappos, 2009): they were asked to stand upright with feet together and eyes closed while the examiner stood close to them observing body swaying. We assigned a RT negative (RT-) status if the RT scored 0, and RT positive (RT+) if RT scored ‡0.

The posturographic measures were collected using a dual fixed static platform (45 × 45 cm, Balance Master® NeuroCom® International, Clackamas, Oregon USA). Subjects wore disposable plastic shoe covers on bare feet to standardize inputs arising from the somatosensory system; the lateral calcaneus position on the platform was determined by a pre-marked line, according to subject height: short, 76–140 cm, medium, 141–165 cm, tall, 166–203 cm. Two tests were adopted: the modified Clinical Test of Sensory Interaction on Balance (mCTSIB) and the LOS. For mCTSIB subjects were asked to stand as still as possible 10 s with eyes open (EO) and then 10 s with eyes closed (EC); this sequence was performed 3 times. COG coordinates, i.e. COG velocity (deg/s) and path length (mm) were collected at a sampling rate of 100 Hz. For each condition (EO and EC) the best trials (with minimum sway) were chosen for analysis.

For the LOS test the subjects were asked to lean far, straight and fast as possible toward targets placed at their 100% theoretical LOS forward (F), right (R) and left (L) and to maintain the maximal leaning position until the end of the trial (lasting 8 s). Each trial was repeated 4 times based on a preliminary study in which the tests were administered several times to a small series of patients: no performance improvement had been observed after the fourth trial (data not shown); the feet were repositioned between the trials, if necessary. Subjects had a real-time feedback of their movements on an height-adjustable screen placed in front of them (Diagram in Supplementary Material).

LOS values were calculated as COG sway angles and expressed as percentage of maximum theoretical LOS as determined by Nashner et al. Balance Manager® Systems (2011). For each direction maximum excursion (% MXE) and directional control (% DCL) of COG were analyzed; the best trial was identified as the one with the highest [% MXE +%DCL]. Both RT and PT were performed in the same session, with the examiner standing 1 m far from the subject; all tests took no more than 15 min.

2.3. Statistical analysis

Demographic data were expressed as medians and ranges; discrete data were given as counts and percentages. Chi square tests were performed to compare groups of categorical data. Normal distribution of posturographic data from HCs was assessed by D′Agostino-Pearson normality test: only the parameters of mCTSIB test showed normal distribution; Mann-Whitney test was adopted to compare values from normal subjects according to heights (cut-off value 165 cm) and age (cut -off values 45 ys); we chose 1st–99th percentiles to define normal threshold of mCTSIB and LOS indexes. To compare posturographic indexes among groups we run the Kruskal–Wallis with Dunn's Multiple Comparison Test. The significance level for statistical analysis was set to 0.05. Analyses were performed using SPSS Statistics for Windows (Version 17.0. Chicago: SPSS Inc). Sensitivity and specificity were