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Posturography using the Wii Balance Board™ A feasibility study with healthy adults and adults post-stroke

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ABSTRACT

Background: Posturography systems that incorporate force platforms are considered to assess balance and postural control with greater sensitivity and objectivity than conventional clinical tests. The Wii Balance Board (WBB) system has been shown to have similar performance characteristics as other force platforms, but with lower cost and size.
Objectives: To determine the validity and reliability of a freely available WBB-based posturography system that combined the WBB with several traditional balance assessments, and to assess the performance of a cohort of stroke individuals with respect to healthy individuals.
Methods: Healthy subjects and individuals with stroke were recruited. Both groups were assessed using the WBB-based posturography system. Individuals with stroke were also assessed using a laboratory grade posturography system and a battery of clinical tests to determine the concurrent validity of the system. A group of subjects were assessed twice with the WBB-based system to determine its reliability.
Results: A total of 144 healthy individuals and 53 individuals with stroke participated in the study. Concurrent validity with another posturography system was moderate to high. Correlations with clinical scales were consistent with previous research. The reliability of the system was excellent in almost all measures. In addition, the system successfully characterized individuals with stroke with respect to the healthy population.
Conclusions: The WBB-based posturography system exhibited excellent psychometric properties and sensitivity for identifying balance performance of individuals with stroke in comparison with healthy subjects, which supports feasibility of the system as a clinical tool.

1. Introduction

The high incidence and prevalence of balance disorders after stroke and their implications for most daily activities make assessment and rehabilitation of balance a priority [1]. Severity of balance deficits have been traditionally assessed using clinical scales [2], which are usually easy to administer in the clinic and not time-consuming. However, balance scales and tests can be influenced by subjective bias and they provide limited sensitivity to, and information about, sensory integration [3].

In the last decade, quantitative assessment has become available through static and dynamic posturography testing [3]. Posturography systems are based on force-plate platforms that estimate the center of pressure (COP) of the subject under study, and evaluate its changes with respect to those from a matched healthy sample. Computerized posturography systems can assess balance and postural control with greater sensitivity and objectivity than clinical instruments, while also quantifying reactions under altered sensory conditions [4]. The negative is that posturography systems are expensive and require a dedicated space in the clinic, which can limit their widespread use [4].

The off-the-shelf Nintendo® Wii Balance Board™ (WBB) is an inexpensive and portable force platform aimed toward allowing users to interact with videogames through postural changes [5]. Interestingly, the WBB has been shown to have validity and reliability similar to the laboratory grade force platforms used in posturography systems [6,7], whose cost is several orders of

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magnitude higher. This fact has motivated an increasing number of studies involving the WBB either as rehabilitation [5] or as an assessment tool [6,8]. Estimations of the path length and the speed of the COP using the WBB have generally shown excellent correlation with those using laboratory-grade platforms [6,7,9,10], across different activities and populations [6,8,10].

Measurements made with the WBB have also shown moderate to excellent reliability [10,11]. A preliminary study has shown promising results at assessing balance and weight-bearing asymmetry following stroke [11]. However, the unavailability of the software, the limited stroke sample, and the absence of a healthy pattern to compare the results could compromise the clinical relevance of these results.

We have designed a web-based tool that allows clinicians to carry out posturographic assessments using the WBB [12]. Benefits of this tool are that it is freely available to the public and that results can be shared among sites. In order to confirm that the tool is a reliable substitution for currently marketed posturography systems, we performed this study to determine the concurrent validity of the WBB-based system with other posturography and clinical tests. Reliability of our tool was quantified through inter and intra-rater reliability, the standard error of measurement, and its minimal detectable change. Finally, we evaluated a cohort of patients with stroke with respect to a group of healthy controls to determine the sensitivity of the WBB-system to motor disability.

2. Methods

2.1. Subjects

To determine the healthy response pattern, individuals older than 10 years old with no known musculoskeletal or vestibular disease and/or prosthetic surgery were recruited. Individuals with stroke were recruited from the outpatient service of the neurorehabilitation unit of the medical center. Inclusion criteria in this group were (1) age $\geq$18 and $\leq$80; (2) ability to stand unassisted for 30 s; and (3) ability to understand instructions (Mini-Mental State Examination [13] >23). Exclusion criteria were (1) individuals with severe aphasia (Mississippi Aphasia Screening Test [14] <45); (2) individuals with permanent fixed contracture of joints in the legs; (3) individuals with arthritic or orthopedic conditions affecting the lower limbs; and (4) individuals with severe hemispatial neglect. Ethical approval for the study was granted by the Institutional Review Board of NISA Valencia al Mar Hospital. All eligible candidates who agreed to take part in the study were required to provide informed consent.

2.2. Instrumentation

A WBB-based posturography system was developed that included three standardized assessment protocols: the modified Clinical Test of Sensory Interaction on Balance (mCTSIB), the Limits of Stability (LOS), and the Rhythmic Weight Shift (RWS) (see Supplementary Material for additional details). The mCTSIB is a simplified version of the Sensory Organization Test [15] that can be carried out using fixed force plates. The test can detect the presence of sensory impairments by analyzing COP motion during quiet stance under four different conditions: eyes opened and closed on a flat surface, and eyes opened and closed on foam. Outcome measures of this test are the speed and the maximum excursion of the COP in the medial-lateral and anterior–posterior axis. The LOS test quantifies maximum displacement of the COP in eight directions while the plantar surface of the feet remains in contact with the platform. Directional control is assessed as a ratio between the extent of movement in the intended direction and the total amount of movement. The outcome measures of this test are the maximum distance and directional control in each direction. Finally, the RWS assesses the ability to rhythmically move the COP in the medial-lateral (ML) and anterior–posterior (AP) planes at three different speeds. The outcome measure of this test was the directional control in both planes at the different speeds.

2.3. Procedure

Healthy individuals were assessed with the three tests of the WBB-based posturography system to describe a healthy response pattern. Subjects were classified in seven decade groups from 10 to 80 years and the average performance of each group in all the tests was computed. Individuals with stroke were also assessed with the WBB-based system and their performance was compared to that of the corresponding age-matched group. In addition, subjects were assessed with the NedSVE/IBV posturography system [16] and with a battery of balance scales to determine concurrent validity of the experimental assessment tool. Posturography assessments were performed barefoot, keeping the feet 20 cm apart in the WBB-based posturography system and placing their feet with the heels together and the toes separated, thus forming a V-shape, in the NedSVE/IBV system, as specified in the manual. Clinical instruments included the Berg Balance Scale (BBS) [17], the Functional Reach Test (FRT) [2], the Step Test with the paretic (STp) and non-paretic leg (STnp) [18], the 30 s Chair-to-Stand Test (30CST) [19], the Timed "Up-and-go" Test (TUG) [20], the Timed Up and Down Stair Test (TUDST) [21], and the 10 Meter Walking Test (10MWT) [22]. All assessments took place within 5 days.

In addition, ten subjects post-stroke were assessed by two different physical therapists to determine inter-rater reliability on the WBB-based system, and other ten subjects were assessed twice by the same physical therapist to determine intra-rater reliability. These tests were performed within the same day.

2.4. Statistical analysis

Pearson correlation coefficients were calculated to determine concurrent validity of the WBB-based posturography with other posturographic and clinical tests. Two statistical indices were used to measure inter and intra-rater reliability. First, paired *t*-tests were performed to examine the changes for statistical significance. Second, a one-way random effects model intra-class correlation coefficient (ICC) was used to summarize the strength of the reliability. Values 0.8 or higher were accepted as indicating excellent reliability. Values in the range of 0.6–0.8 and 0.4–0.6 indicated high and moderate reliability, respectively. The standard error of measurement (SEM) and the minimal detectable change (MDC) were also obtained. MDC scores > 30% were considered poor, from 10% to 30% were considered acceptable, and <10% were considered excellent.

Finally, as it was previously mentioned, healthy controls were categorized into age groups by decade. For each age range, a cumulative frequency distribution of the raw scores of each posturographic measure was estimated. Raw scores of individuals with stroke on each posturographic measure were converted to percentile scores derived from the frequency distribution of the age-matched healthy sample, thus representing their position with respect to the normative values. Percentile scores above the 16th percentile were considered not altered. Percentile scores between the 16th and the 2nd were considered mildly altered. Percentile scores below the 2nd percentile were considered severely altered. All statistical analyses were performed using IBM SPSS Statistics version 22 (IBM, New York, NY). Two-sided *p*-values of <0.05 were considered statistically significant.