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Measuring standing balance in multiple sclerosis: Further progress towards an automatic and reliable method in clinical practice

Philipp M. Keune [a,b,*], William R. Young [c], Ioannis T. Paraskevopoulos [d], Sascha Hansen [a], Jana Muenssinger [a], Patrick Oschmann [a], Roy Müller [a,e,f]

[a] Department of Neurology, Klinikum Bayreuth GmbH, Germany
[b] Department of Physiological Psychology, Otto-Friedrich-University Bamberg, Germany
[c] Department of Clinical Sciences, Brunel University London, United Kingdom
[d] Department of Computing and Information Systems, University of Greenwich, London, United Kingdom
[e] Department of Orthopedic Surgery, Klinikum Bayreuth GmbH, Germany
[f] Department of Sports Science, Friedrich-Schiller-University, Jena, Germany

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ABSTRACT

Background: Balance deficits in multiple sclerosis (MS) are often monitored by means of observer-rated tests. These may provide reliable data, but may also be time-consuming, subject to inter-rater variability, and potentially insensitive to mild fluctuations throughout the clinical course. On the other hand, laboratory assessments are often not available. The Nintendo Wii Balance Board (WBB) may represent a low-cost solution. The purpose of the current study was to examine the methodological quality of WBB data in MS (internal consistency, test-retest reliability), convergent validity with observer-rated tests (Berg Balance Scale, BBS; Timed-Up and Go Test, TUG), and discriminative validity concerning clinical status (Expanded Disability Status Scale, EDSS).
Methods: Standing balance was assessed with the WBB for 4 min in 63 MS patients at two assessment points, four months apart. Additionally, patients were examined with the BBS, TUG and the EDSS.
Results: A period of 4 min on the WBB provided data characterized by excellent internal consistency and test-retest reliability. Significant correlations between WBB data and results of the BBS and TUG were obtained after merely 2 min on the board. An EDSS median-split revealed that higher EDSS values (>3) were associated with significantly increased postural sway on the WBB.
Conclusions: WBB measures reflecting postural sway are methodologically robust in MS, involving excellent internal consistency and test-retest reliability. They are also characterized by convergent validity with other considerably lengthier observer-rated balance measures (BBS) and sensitive to broader clinical characteristics (EDSS). The WBB may hence represent an effective, easy-to-use monitoring tool for MS patients in clinical practice.

1. Introduction

Balance deficits are frequent in Multiple Sclerosis (MS), require continuous monitoring [1–3] and represent a threat for affected patients as they may increase the risk for falls [4]. For clinical routine examinations, several observer-rated or timed tests are available, e.g. the Berg Balance Scale (BBS) [5] and the Timed-Up and Go Test (TUG) [6]. Both tests provide reliable clinical data [7], however, particularly an extensive procedure such as the BBS may be time-consuming, involving a duration of approximately 20 min to administer the test [8].

Complementary to observer-rated tests, electronic force platforms may be regarded as the gold-standard of balance assessments [9,10]. As they often have to be implemented in a laboratory setting, however, they are also costly and often not available in routine clinical practice. The portable, user-friendly Nintendo Wii Balance Board (WBB) may represent a low-cost alternative [11,12] and has gained popularity as an application in MS research. Initial studies used the WBB as a *training device* [13–17], but it could also be used as a *tool to measure posturography* [18]. The WBB appears sufficiently accurate in quantifying centre of pressure (COP) trajectory during stance balance tasks and can be interfaced with any regular laptop with an appropriate software environment [11,19]. Nevertheless, only a few studies explored

* Corresponding author at: Department of Neurology, Hohe Warte 8, 95445 Bayreuth, Germany.
E-mail addresses: philipp.keune@klinikum-bayreuth.de (P.M. Keune), Will.Young@brunel.ac.uk (W.R. Young), I.Parask@greenwich.ac.uk (I.T. Paraskevopoulos), sascha.hansen@klinikum-bayreuth.de (S. Hansen), jana.muenssinger@klinikum-bayreuth.de (J. Muenssinger), patrick.oschmann@klinikum-bayreuth.de (P. Oschmann), roy.mueller@klinikum-bayreuth.de (R. Müller).

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the potential value of the WBB as a monitoring and diagnostic tool in MS [20,21]. This is striking, as the WBB could potentially be utilized to conduct automatic, time-effective and standardized assessments to monitor balance performance in MS. Such assessments would be unaffected by inter-rater variability, while availability would be generally given due to the low cost of the WBB.

In a pioneering study, Castelli et al. [20] examined MS patients and healthy controls in a single day session by means of a standard force platform and the WBB. Between device reliability was adequate, test-retest reliability was excellent and the WBB showed similar performance in discriminating retrospectively reported fallers from non-fallers as the standard force platform. The latter finding complements observations from studies in which the extent of trunk-sway and posturographic data on various balance tasks was shown to be associated with scores on the Expanded Disability Status Scale (EDSS) [22–24]. In another study, Severini et al. [21] reported that the WBB and a force platform showed a similar classification of MS patients vs. healthy individuals (>80%), albeit it was also shown that the WBB does not provide absolute measures of postural sway with the same precision as a force platform.

The current study was intended to diversify previous findings [20, 21] and to readdress the issues of reliability and validity of the WBB in MS. While previous work provided support for convergent validity of the WBB with a standard force platform (gold standard), there remains a knowledge gap as to whether the WBB also provides convergent validity with other commonly used measures of balance and motor performance in clinical practice. Reports on test-retest reliability in the study by Castelli et al. [20] were also based on observations that occurred on the same appointment, yielding a knowledge gap as to whether the WBB provides sufficient test-retest reliability in MS throughout longer periods. This may be important for the use of the WBB in longitudinal studies, for which it might represent a monitoring device. Additionally, the basic methodological issue, whether WBB data show sufficient internal consistency during the same assessment, was not considered in previous work.

Based on these considerations, the main hypotheses of the current study are as follows: It was assumed that (a) WBB data would display sufficient internal consistency across 4 min of recording and sufficient test-retest reliability across assessments separated by four months. It was also assumed that (b) WBB data would be significantly correlated with performance on a lengthier observer-rated test (BBS) and the TUG. Finally, it was expected that (c) WBB measures would be sensitive to clinical characteristics in MS patients, as specified by the EDSS.

2. Methods

2.1. Participants

The study was approved by the ethics committee of the University of Bamberg, Germany. All participants provided written informed consent. MS patients were recruited in the Department of Neurology, Klinikum Bayreuth GmbH, Germany. Patients were eligible to participate in case of a verified MS diagnosis [25], or clinically isolated syndrome (CIS) and the ability to stand without support for at least 5 min. Patients were not included in case of a recent treatment change or relapse, i.e. clinical status had to be stable for at least two months. Patients who experienced a relapse between the two assessment points were excluded from any analysis involving the second assessment point. Patient demographics and clinical characteristics are reported in Table 1.

Table 1
Demographical and clinical characteristics of the sample.

	CIS	RR-MS	SP-MS	Total
N	3	45	15	63
Age				
Mean	30.3	35.5	49.9	38.7
SD	6.7	8.9	6.0	10.4
Min	23	20	36	20
Max	36	55	60	60
Female sex	2	36	13	51
EDSS				
BMI				
Mean	23.3	23.8	24.7	24.0
SD	1.9	1.3	0.5	1.5
Median	1	2	4	2.5
SD	0.6	1.3	0.5	1.5
Min	0	0	4	0
Max	1	5	6	6
Disease duration (years)				
Mean	2.0	7.5	12.9	8.5
SD	2.6	6.3	5.5	6.5
Min	0	0	4	0
Max	5	23	22	23

Note. EDSS = Expanded Disability Status Scale, SD = standard deviation.

2.2. Procedure

Participants were examined at two assessment points (Time 1, Time 2) during routine clinical appointments (interval between assessments: M = 4.1 months, SD = 2.2). Out of 63 participants who were recruited and examined at Time 1, 54 also completed the Time 2 assessment. The remaining nine participants were not available for the Time 2 assessment due to various reasons including a change in residence or medical centre, or deterioration in clinical status that prevented further participation. Out of the 54 patients who were retested at Time 2, n = 4 experienced a relapse between assessments. Datasets of these patients were excluded from the further analysis focusing on test-retest reliability and internal consistency at Time 2. EDSS values in retested patients remained identical across the two assessments (median: 2.5, range 0–6).

At each point, patients completed a four-minute assessment on the WBB consisting of a sequence of one-minute eyes-open (O) and eyes-closed (C) trials, in the order: O-C-O-C. Hence, trials 1 and 3 were eyes-open trials whereas trials 2 and 4 were eyes-closed trials. Patients were instructed to stand on the board and to minimize postural sway, placing their feet symmetrically on the board by fitting a marked area for each foot, respectively. The two conditions were included based on the rationale that standing with eyes-closed might pose an additional challenge to patients' balance control, and might be accompanied by increased variance in postural sway, relative to eyes-open trials. Following this reasoning, an exploratory analysis could be implemented to test whether internal consistency or test-retest reliability varied across these conditions. For both conditions, patients were instructed to stand still on the board and to minimize their postural sway.

To address the question whether the WBB provides informative data with regards to balance performance and clinical characteristics, MS patients also completed classic measures of balance performance, i.e. the BBS and TUG, as well as the EDSS. The latter measures were administered at Time 1.

2.3. Measures of balance performance

The WBB (approximate dimensions: 50 by 30 by 5 cm) contains four weight sensors. Based on the weight distribution across these sensors, the location of the centre of pressure (COP) of a patient standing on the board was continuously recorded during the four-minute assessment periods at Time 1 and Time 2. To this end, the WBB was bluetooth interfaced with a laptop and COP path length was continuously recorded by utilizing an open source software library (WiiYourself[1]). The same library was employed to process the data packets and separate effective sensor information from the peripheral data, such as connection flag data [12]. The frequency of sampling the raw data is inherent by the

[1] WiiYourself – http://wiiyourself.gl.tter.org/