Wii Balance Board: Reliability and Clinical Use in Assessment of Balance in Healthy Elderly Women

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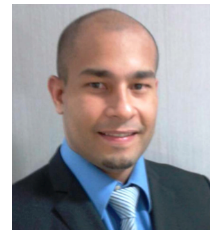

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Abstract: Force plate is considered gold standard tool to assess body balance. However the Wii Balance Board (WBB) platform is a trustworthy equipment to assess stabilometric components in young people. Thus, we aim to examine the reliability of measures of center of pressure with WBB in healthy elderly women. Twenty one healthy and physically active women were enrolled in the study (age: 64 ± 7 years; body mass index: 29 ± 5 kg/m^2). The WBB was used to assess the center of pressure measures in the individuals. Pressure was linearly applied to different points to test the platform precision. Three assessments were performed, with two of them being held on the same day at a 5- to 10-minute interval, and the third one was performed 48 h later. A linear regression analysis was used to find out linearity, while the intraclass correlation coefficient was used to assess reliability. The platform precision was adequate (R^2 = 0.997, P = 0.01). Center of pressure measures showed an excellent reliability (all intraclass correlation coefficient values were > 0.90; $p < 0.01$). The WBB is a precise and reliable tool of body stability quantitative measure in healthy active elderly women and its use should be encouraged in clinical settings.

Keywords: Testing reproducibility, ageing, posture, rehabilitation, center of pressure, health impact assessment, postural balance.

INTRODUCTION

Balance is an important physical capability for developing activities of daily living [1, 2]. Elderly and people with neurological or musculoskeletal disorders have their balance affected on the basis of a sensory deficit [3]. However, the accurate assessment of this variable requires sophisticated and onerous equipment.

Balance measurement can be performed with the force plate [4], scales [5] or specific clinical tests [6]. The force plate is considered the gold standard method for this assessment [7], consisting of strain gages that transduce mechanical deformation to forces (Z = vertical force; Y = anteroposterior force; and X = mediolateral force) applied to its surface. The net force is the center of pressure (CoP), which provides variables related to postural balance, such as displacement over time, oscillation area, and displacement velocity [8-10].

The CoP is identified as an XY plane spatial coordinate, the net force resulting from the ground reaction forces. CoP spatial position changes according to the displacement of the body's center of gravity (CG) (*e.g.*, shoulder at 90-degree extension). The net force vector equals the mean position of the forces acting on the plate in the opposite direction [10]. Thus, the magnitude really indicating body displacement is CM positioning variation. Therefore, the CoP is an expression of the neuromuscular response to CM displacement.

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The CoP is associated with a position measure defined by two coordinates in the plate surface and the position of the person being assessed. According to the signals recovered from the force plate, the CoP position in mediolateral and anteroposterior directions is calculated by equations involving the supporting base height above the plate sensors and the components of force and moment of force [9, 10]. However, this equipment is not easily acquired, carried and operated. Therefore, good quality tools with a better cost-benefit should be developed, as the feasibility of a precise and reliable assessment of body stability can facilitate decision-making when prescribing physical training and rehabilitation programs.

Recently, Clark and colleagues [7] tested reliability and validity of the Wii Balance Board (WBB), an accessory of Nintendo® Wii videogame (Nintendo, Japan), regarding a force plate for laboratory use. Total XY plane CoP displacement in healthy adults was assessed and the results found were promising in three out of four conditions assessed in protocols frequently used in studies (eyes open and bipodal support on the plate (EOB); eyes open and unipodal support on the plate (EOU); eyes closed and bipodal support on the plate (ECB); eyes closed and unipodal support on the plate (ECU). These tests assessed the CoP total displacement variable. Three out of four tests showed good reproducibility (EOU, R = 0.76; ECB, R = 0.91; and ECU, R = 0.81). Curiously, the test that was theoretically supposed as the easiest to be carry out (EOB) did not have good results for reliability (R = 0.66).

By facing this new perspective of body stability assessment and the clinical need of a reliable tool to assess stabilometric components, new investigations with WBB assessing different population samples, such as the elderly, are needed. Aging leads the individual to a decline of sensory information processing, which reduces body stability [11]. In this setting, though the seminal study by Clark and colleagues [7] showed WBB reliability and validity in assessing young people, body balance variability in the elderly could interfere with the stabilometric measure due to an increased use of hip strategy and reduced ankle strategy for balance [12]. Furthermore, only the reproducibility of CoP total displacement measure (XY plane) was investigated in this study [7], demonstrating the need of studies examining the measures in X and Y planes separately, as the analysis of mediolateral and anteroposterior axis may improve decision-making as to intervention. In addition, variables such as CoP velocity, possibly indicating neurological conditions [13], deserve investigation for the measure reproducibility.

As this is a new assessment tool, the presence of a large amount of evidence is important to raise the consistency of information to be used. We could take as an example the studies analyzing the reliability of stabilometric variables measured with a force plate. Despite its vast scientific applicability over the last 13 years, only seven studies of elderly have been reported [14]. Thus, the objective of this study was to analyze the precision and find the intra-rater and inter-day reliability of measuring stabilometric variables in XY plane and in mediolateral and anteroposterior axis with WBB in healthy and physically active elderly women.

MATERIALS AND METHODS

Sample

Twenty-one healthy women (age: 64 ± 7 years; BMI: 29 ± 5 kg/m^2) engaged in an aqua-aerobics program two to three times a week were enrolled. The following inclusion criteria were adopted: a) no acute injury in lower limbs; and b) no pain symptom whatsoever. The subjects were excluded if they reported: a) recent surgery; b) labyrinthitis with no drug control; c) neurological conditions. These criteria were ascertained through the history taken. All volunteers signed the informed consent form after an account on the study objective in accordance with the rules of the law 196/96 of the National Health Council. The project was approved by the Ethics Committee in Clinical Research of Gama Filho University under the number 153/2011 (CAAE 0139.0.312.000-11).

Equipment

The WBB balance platform of Nintendo® Wii videogame with a surface area of 45 cm x 26.5 cm was used. This platform consists of four load sensors (Fig. **1**), with their communication with the data acquisition device being established *via* Bluetooth.

WBB equations for locating the CoP are similar to those used in the force plate. However, the WBB does not provide data regarding force Z. The CoP is calculated by using the equations 1-2, considering the left and right upper and lower sensors [15] (Fig. **1**):

(1) CoPx = 21 x [C + D – (A + B) / (A + C + B + D)]

(2) CoPy = 12 x [A + C – (B + D) / A + C + B + D],

where 21 and 12 are the height and length (cm) of the plate base with respect to the central line and the letters are load sensors.

A programming routine using the LabVIEW software version 8.5 (National Instruments, Texas, USA) was designed for data acquisition and reading, being installed on a computer (for the detailed procedure, v. Attachment 1). The device calibration was automatically programed into the application routine. However, a procedure to find whether pressure points were linearly applied in platform known distances (5, 10, 15, and 20 cm from the central line) was performed to ensure the equipment precision.

The stabilometric signal was obtained in a sampling frequency of 40 Hz. A Butterworth eighth-order low-pass filter with a 12-Hz cut-off frequency was used to eliminate potential interference. First, we used the same filter configuration as that in Clark and colleagues [7] study to allow study comparison. As we were aware of the possible phase delay due to the relative high order of the filter, it was implemented in direct and reverse order in SuiteEBG software, thus ensuring no phase delay in the time series filtered [16].

The signal processing was performed by using the postural balance assessment software (Suite EBG) developed in language LabVIEW 8.0 for Windows.

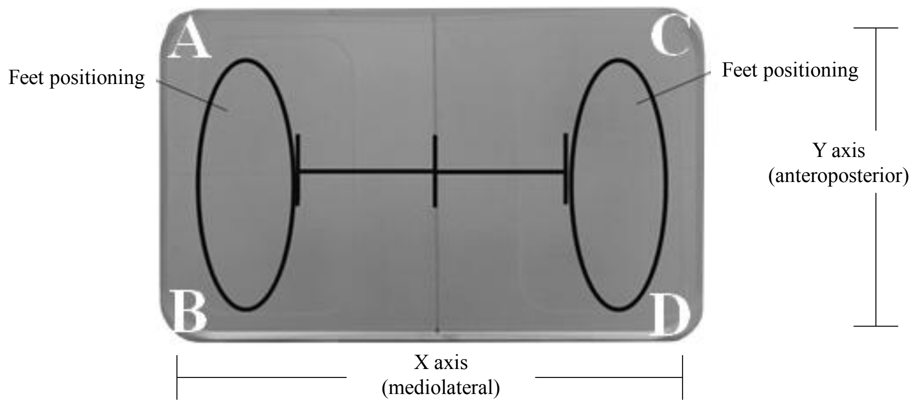

Fig. (1). Feet positioning on the balance platform for Wii Balance Board®. A and B, left upper and lower sensors; C and D, right upper and lower sensors. X and Y are spatial coordinates. This protocol was applied for all individuals to reduce bias. Distance of feet was recorded previously for each person.

Procedures

The total collection period was 60 days (from the first to the last subject). This procedure was adopted in line with the subjects' enrollment to optimize the number of assessments a day so that the rater would not be overloaded and potential data interference could be avoided.

The subjects underwent the positioning protocol on the stable platform as seen in Fig. (**1**). Every individual was instructed to assume a comfortable positioning with their feet not surpassing a line from their shoulders (feet positioning aligned to shoulders). This positioning was imprinted in a paper mold posted on the platform so that the protocol could be reproduced each assessment. Every subject was instructed to keep her arms alongside her body and look at a fixed point located two meters away.

The individuals attended to two laboratory visits. At the first visit, the measure internal consistency was assessed. The following variables were studied: total CoP displacement (cm), mean CoP velocity (cm/sec), standard deviation of the CoP mediolateral displacement (cm) and standard deviation of the CoP anteroposterior displacement (cm). The subjects underwent the tests with eyes open and bipodal support (three measurements) and then with eyes closed and bipodal support (three measurements). A 5-minute interval was allowed and the procedure was repeated soon after it. The mean of the three assessments with eyes open and the mean of the three assessments with eyes closed were used to interpret e process the data.

At the second visit, which occurred 48 h after the first visit, the variables above mentioned were collected again. This procedure was adopted so that the consistency of the measurement could be ascertained on different days.

A physiologist specialized in musculoskeletal rehabilitation was trained in stabilometry signal acquisition and processing for about one month so that he could make the assessment.

Data Analysis

The statistical package used to analyze data was SPSS 17. The results are shown in mean and standard deviation. A linear regression was used to analyze the linearity between pressure points applied in calibration. Data from assessment obtained at the first visit were analyzed to find the measure internal consistency. The intraclass correlation coefficient (ICC) was used in the analysis. The significance level was considered $p<0.05$. The following ICC classification was adopted: ICC > 0.90 = excellent correlation; 0.80 to 0.89 = moderate correlation; and < 0.80 = non acceptable correlation [17]. The calculation proposed by Hopkins [18] was used to quantify the typical error of measurement (absolute and relative TEM), while considering Bland-Altman's 95% confidence limits.

RESULTS

Accuracy of Platform

The points of pressure application on the platform showed linearity ($R^2 = 0.997$, $p = 0.01$), which exhibits the equipment precision (Fig. **2**).

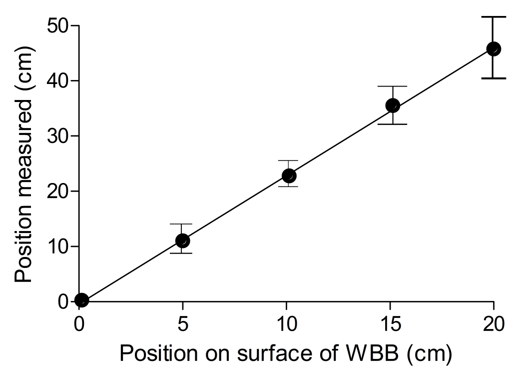

Fig. (2). Accuracy of measure in different places of platform. A) Mean and standard deviation of pressure points applied for calibration at known distances from the platform central line ($R^2 = 0.997$; $p < 0.05$); B) Spatio-temporal graph show a group of pressure points in each distance.

Reliability

The CoP displacement (cm), the mean CoP velocity (cm/sec), and the standard deviation in mediolateral and anteroposterior axis showed excellent correlation ($R > 0.90$; $p < 0.05$) (Tables **1** and **2**).

Table 1. Intra-rater (within-day) reliability of CoP measurements (cm).

Variable	1st Measurement		2nd Measurement		ICC	Variation
	Mean	SD	Mean	SD	R	%
Dis EO	83.87	44.16	79.04	34.52	0.978*	5.75
Dis EC	94.13	49.14	89.00	43.30	0.989*	5.44
MV EO†	2.79	1.48	2.63	1.16	0.978*	5.73
MV EC†	3.14	1.65	2.97	1.46	0.989*	5.41
SD X EO	0.23	0.15	0.23	0.15	0.994*	0
SD X EC	0.24	0.15	0.24	0.15	0.985*	0
SD Y EO	1.07	0.50	1.04	0.46	0.982*	2.80
SD Y EC	1.11	0.59	1.10	0.56	0.995*	0.90

Note. EO, Eyes Open; EC, Eyes Closed; Dis, Displacement; MV, Mean Velocity; SD, Standard Deviation; X, Horizontal Axis; Y, Vertical Axis.
†Unit in cm/sec
*p < 0.01.

Table 2. Between-day reliability of CoP measurements (cm).

Variable	1st Measurement		2nd Measurement		ICC	Variation
	Mean	SD	Mean	SD	R	%
Dis EO	83.87	44.16	87.39	42.05	0.984*	4.02
Dis EC	94.13	49.14	90.18	44.72	0.997*	4.19
MV EO†	2.79	1.48	2.91	1.40	0.984*	4.12
MV EC†	3.14	1.65	3.01	1.49	0.997*	4.14
SD X EO	0.23	0.15	0.24	0.15	0.977*	4.16
SD X EC	0.24	0.15	0.24	0.14	0.941*	0
SD Y EO	1.07	0.50	1.13	0.53	0.954*	5.30
SD Y EC	1.11	0.59	1.14	0.57	0.971*	2.63

Note. EO, Eyes Open; EC, Eyes Closed; Dis, Displacement; MV, Mean Velocity; SD, Standard Deviation; X, Horizontal Axis; Y, Vertical Axis.
†Unit in cm/sec.
* p < 0.01.

Error of Measurement

Absolute and relative values of TEM were calculated. These values showed a bit variation (< 20%). These values are shown in Table **3**.

DISCUSSION

This study aimed to analyze the precision and find the reliability of measuring stabilometric variables of the WBB in healthy and physically active elderly women. According with results, WBB is a body stability assessment tool with excellent measurement reliability in line with the ICC classification adopted [17]. These results should be taken into account mainly for their reliability, but also for the low cost to acquire the device (about US$ 200), operability and easy transportation.

The Use of WBB in Clinical Settings

One of the greatest difficulties in clinical setting is quantitatively assessing one treatment efficacy. Usually the health professional relies either on the patient's subjective response or on poorly consistent observations. Regarding body balance control disorders, a few scales and test batteries are used to assess this physical characteristic [5, 19-21]. However, although these tools are practical and useful, they are not very sensitive for a good identification of balance control changes. Thus, the need of a precise and reliable equipment for stabilometric assessment is evident.

The gold standard for stabilometry is the force plate, but the cost to acquire this tool is high (between US$5,000 and US$25,000), making limited the propagation of this assessment tool in the clinical setting. Thus, WBB use should be encouraged, as its application seems to be valuable for health professionals. In addition to data shown in this study, it is important to highlight the WBB demonstrates measurements similar to those seen with the force plate [7], further increasing the perspective to use it. Moreover, the results described in this report show superior correlation values, compared with other reports in the literature [7]. In addition, our data expresses the typical error of measurement, which enables data collected to be adjusted in stabilometry through instrumental variation of the

Table 3. Typical error of intra-rater CoP spatial measurements, considering Bland-Altman's confidence limits (95%).

Variable	Within-Day		Between-Day	
	TEM (cm)	TEM (%)	TEM (cm)	TEM (%)
Dis EO	3.09	4.11	4.73	5.97
Dis EC	3.54	4.29	2.05	2.48
MV EO†	0.04	2.15	0.16	5.92
MV EC†	0.11	4.08	0.13	4.78
SD X EO	0.01	6.58	0.02	10.45
SD X EC	0.01	7.31	0.04	18.18
SD Y EO	0.05	6.02	0.12	11.80
SD Y EC	0.04	3.97	0.09	8.98

Note. TEM, Typical Error of Measurement; EO, Eyes Open; EC, Eyes Closed; Dis, Displacement; MV, Mean Velocity; SD, Standard Deviation; X, Horizontal Axis; Y, Vertical Axis.
†Unit in cm/sec.

measurement. In practical terms, the variables studied can be used pre- and post-intervention to ensure that benefits related to body balance have indeed been reached. The results obtained from this kind of investigation can be adjusted in accordance with the error magnitude. Therefore, strategies of periodical stabilometric assessment can be designed, aiming to facilitate the clinical decision-making towards interventions provided. However, the elderly women considered in this study were physically active and, in case sedentary elderly individuals are assessed, the results must be interpreted with caution.

Reliability of Different Variables

The need to study the WBB reliability was driven not only by the cost-benefit, but also by the measurement reproducibility divergence of a few variables identified in studies with the force plate [22, 23]. Variables such as the total displacement, displacement area, displacement velocity, among others, showed some inconsistency when analyzed in different times. As those measurements had excellent intraday and between-day reproducibility in the current study, except for displacement area (not analyzed), this results had increased inference consistency for WBB use.

One of the factors showing the importance of results in this study is taking into account the subjects' age. As the body balance is prone to be reduced as a function of aging [12, 24], having an precise and reliable tool for quantitative assessment of that physical characteristic will enable practices and gyms to improve diagnosing, managing, and training. However, as observed from the standard deviations in Tables **1** and **2**, precautions in assessments, such as the assessment time and drug use, are important to reduce the variability.

Feasibility to Assessment

Another important aspect is the WBB applicability in different sites, as the equipment (WBB platform and notebook) transportation is easy. Thus, research settings where the assessed individuals find it difficult to reach the laboratory might be led more easily. Furthermore, assessment with WBB could be conducted on sports fields (before or after training/competition), which would be very difficult with a gold standard force plate.

Over the last years, the interest of exercise and health investigators in using the WBB either in training [25-27] or in treating [28] and assessing [7, 29, 30] has increased. This fact shows the potential the equipment has and how it can be used in interventions. In addition, the WBB precision and reproducibility of measurements reinforce the possibility of its alternative laboratory use, once the spatial position reading of the center of pressure is consistent with the gold standard [7]. Thus, we speculate researchers might benefit from these findings to conduct future investigations in the area.

CONCLUSION

WBB is a precise and reliable tool of quantitative measurement of body stability and, therefore, its use should be encouraged in the clinical setting. The assessment of stabilometric components with the WBB may positively affect diagnosing and enhance interventions to improve body balance in the elderly. In addition the low cost and the usability of this equipment could increase the range of professionals that could use this type of force plate.

LIST OF ABBREVIATIONS

CM	=	Center of Mass
CoP	=	Center of Pressure
ECB	=	Eyes Closed Bipodal
ECU	=	Eyes Closed Unipodal
EOB	=	Eyes Open Bipodal
EOU	=	Eyes Open Unipodal
WBB	=	Wii Balance Board

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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