ASSESSMENT OF BALANCE ABILITIES IN ELDERLY PEOPLE BY MEANS OF A CLINICAL TEST AND A LOW-COST FORCE PLATE

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Abstract:

Balance and mobility assessment, and the estimation of the risk of falls, represent crucial elements for supporting a healthy aging process. In this work, we evaluated the association of two approaches used to estimate standing balance and sit-to-stand abilities in community-dwelling older people. The clinical-based test was the *Short Physical Performance Battery*, while the laboratory-based assessments were realized by means of output measures obtained with the Wii Balance Board. The correlation between clinical scores and laboratory measures showed poor association for the standing balance test ($.05<r<.37$) and modest association for the sit-to-stand test ($-.31<r<.73$), respectively. Linear regression analysis was in agreement with these findings, and it revealed a model for standing balance that explained 14% of the association, and a model of sit-to-stand that explained 69% of the association. Discriminant function analysis showed significant classification agreement between the two approaches, but with different levels of accuracy. The rate of accuracy for the standing balance test was 63.3%, while for the sit-to-stand test the rate of accuracy was 92.2%. For both tests, these values were lower after a cross-validation procedure. The values of root mean square of the center of pressure was a significant predictor for different ability levels in the standing balance test, while the vertical component of the ground reaction force and the overshoot were the predictors for sit-to-stand ability levels. These findings seem to support the feasibility of using the Wii Balance Board for the assessment of balance and sit-to-stand abilities in elderly people. Therefore, medical practitioners could use this device with the clinical test for obtaining more useful information for their analysis.

Key words: *standing balance assessment, sit-to-stand assessment, short physical performance battery, Wii Balance Board*

Introduction

Each year one-third of European elderly people over 65 fall during their daily activity. This rate becomes higher for people over 75 (WHO, 2008), and these findings are in agreement with those detected in community-dwelling older adults (Skelton & Todd, 2004). Several elements have been accounted for to explain the fall risk in older people, such as intrinsic (age, gender, balance) and extrinsic factors (environmental hazards, footwear). Among the intrinsic factors, balance and mobility impairments have been indicated as the best predictors of fall risk (Stel, Smit, Pluijm, & Lips, 2003). Balance ability is related to the maintenance of proper postural coordination in many motor activities, such as sitting or standing, and in the transition phases among postures (Mancini & Horak, 2010). People with low levels of balance ability have shown difficulties in their daily activities where sit-to-stand (STS) motor strategy is needed (Whitney, et al., 2005). Several studies have outlined the relation between sit-to-stand performance and postural control in standing posture (Schenkman, Hughes, Samsa, & Studenski, 1996), while others have discussed the role of sit-to-stand motor competence as a predictor of fall risk (Regterschot, et al., 2014). The assessment of standing balance aims to identify the presence of problems and to establish the relative underlying cause, and it is usually realized by means of clinical assessment tests and objective measures. In elderly people, the clinical assessment focuses on the level of proficiency, and it can be used to predict their fall risk (Perell, et al., 2001).

The clinical test for balance and mobility assessment rates the performance of several specific motor tasks, such as static and dynamic balance posture or safe mobility-related activities (i.e. gait, rising from a chair). The clinicians use a skill criteria observational grid, a three-to-five point scale, or the Likert scale for the evaluation of the clinical test. The tests that therapists use the most are: *Activities-Specific Balance Confidence Scale* (ABC) (Powell & Meyers, 1995), *Berg Functional Balance Scale* (Berg, Wood-Dauphinee, Williams, & Maki, 1992; Berg & Norman, 1996), *Tinetti Balance and Gait Assessment* (Tinetti, 1986), *Timed up and go* (TUG) (Mathias, Nayak, & Isaacs, 1986), *Functional Reach* (Duncan, Weiner, Chandler, & Studenski, 1990) and *Short Physical Performance Battery* (SPPB) (Guralnik, et al., 1994). The SPBB test includes three different feet position tests for assessing standing balance abilities, and a sit-to-stand test for the assessment of motor strategy used for rising from a chair. Each of the two separate components is a grade test, and their outcomes may be understood as the ability level of the participants. The good results about the validity and reliability of the SPPB test in community cohorts have been recently discussed in literature (Freire, Guerra, Alvarado, Guralnik, & Zunzunegui, 2012). Moreover, this test could be used to define ability level groups, which is useful for the comparison with other approaches (Olvera-Chávez, Garza-Hume, Gutiérrez-Robledo, Arango-Lopera, & Pérez-Zepeda, 2013). The clinical assessment tests have shown the following limits: low level of inter- and intra-rater reliability, poor aptitude at detecting the abilities' changes, and poor capacity to identify the main balance problems (Mancini & Horak, 2010).

Laboratory-based tests for balance assessment seem to solve the previous limits because they provide objective, reliable, valid, practical, and more sensitive measures in respect to balance ability (Mancini & Horak, 2010; Nguyen, et al., 2012). The laboratory-based tests are usually implemented in clinical laboratories using specific devices. A force plate is considered the gold standard instrument for assessing balance and sit-to-stand performances (Huurnink, Fransz, Kingma, & Dieën, 2013). The balance ability levels are mainly measured by means of the posturography parameters; these parameters have been discussed as predictors of balance disorders and fall risk (Stel, et al., 2003). In the elderly population, the ability levels of the motor strategy used to carry out the rising from a chair task are usually addressed with several biomechanical indexes (e.g. peak vertical ground reaction forces, timing of sit-to-stand phases) (Alexander, Schultz, & Warwick, 1991; Schultz, Alexander, & Ashton-Miller, 1992; Hughes, Weiner, Schenkman, Long, & Studensky, 1994; Thapa, Gideon, Fought, Kormicki, & Ray, 1994; Hughes & Schenkman, 1996; Schenkman, et al., 1996; Judge, Schechtman, & Cress, 1996). The laboratory-based approach also has several limits: the assessment sessions cannot be realized in-field and require high-cost technologies (Clark, et al., 2010). The use of Wii Balance Board (WBB) has been proposed as one solution for the aforementioned limits (Clark, et al., 2010; Huurnink, et al., 2013). The Wii Balance Board is a promising low-cost device recently used for the training and physical assessment in elderly people (Young, Ferguson, Brault, & Craig, 2011; Goble, Cone, & Fling, 2014;); furthermore, the Wii Balance Board showed high validity and concurrent reliability for the assessment of balance control (Scaglioni-Solano & Aragon-Vargas, 2014; Sgrò, Monteleone, Pavone, & Lipoma, 2014).

In this study, we investigated the feasibility of using the Wii Balance Board as an instrument for the assessment of balance and mobility proficiency in community-dwelling older people. In this respect, and according to the suggestions provided by previous studies (Adkin, Frank, & Jog, 2003; Blum & Korner-Bitensky, 2008), we propose the combination of a clinical test (i.e. SPPB) with the measures acquired from the Wii Balance Board. The clinical test was used to define the ability levels in balance and sit-to-stand tasks, while the Wii Balance Board measures were used for estimating posturography and biomechanical parameters related to the aforementioned tasks. We hypothesize the following: (H1) the results of the clinical test are in relation to the measures obtained from the Wii Balance Board, and (H2) the Wii Balance Board output measures can discriminate the ability levels in standing balance and sit-to-stand tests.

Methods

Subjects and procedure

The participants in this research were recruited from the elderly hosted in a community. All the guests without serious neurological and/or musculoskeletal impairments that might limit their balance abilities were invited to participate in the research. Thirty-four of them accepted and provided their informed consents. Data on anthropometric characteristics, and the number of falls in the last year for each participant were provided by the community medical center. The participants were ten males and twenty-four females with the following characteristics: [mean (min-max): age 85 (64.0-92.0) years; body height: 1.53 (1.41-1.74) cm; body mass: 61.47 (45.0-98.0) kg; number of falls per year: 0.38 (0-2)].

The participants were randomly allocated to five groups with four to seven participants per group. The assessment procedures were scheduled on two days and they were conducted in the community's gymnasium. The assessment order was randomized by means of a random number assigned to each group's participant. Two operators with the same background of physical skill assessment were involved in this study. They described the procedure of each test to the subjects before the evaluation. The assessment of standing balance and sit-to-stand ability levels was realized by means of a clinical approach and quantitative techniques described in the next subsections. The Ethical Committee of the Community and the Ethical Board of the University of Enna approved the samples, procedures, and devices used in this study.

Clinical assessment approach

The SPPB includes a graded test for assessing the ability levels of standing balance, walking and sit-to-stand tasks. In this work, we addressed the standing balance and sit-to-stand abilities, and we considered the score obtained in each of the components as a relative ability level.

To assess standing balance, the time of three different feet position-based balance performances was evaluated. The feet positions were: side-by-side, semi-tandem, and full tandem. According to the procedures proposed by Guralnik and colleagues (1994), each subject began with the semi-tandem position (the heel of one foot was placed on the side of the first toe of the other foot). If a participant was not able to maintain the semi-tandem position for ten seconds, he/she was evaluated in the side-by-side test (the feet were placed in the same line). If the participants maintained the side-by-side position for ten seconds, the score was 1, otherwise the score was 0. If a participant maintained the semi-tandem position for ten or more seconds, he/she was further tested in the full-tandem position (the heel of one foot was directly in front of the other foot). If the full-tandem position was sustained for the maximum of two seconds, the score was 2. The score 3 was assigned if the full-tandem position was maintained from three to nine seconds. If the full tandem time was ten seconds, or more, the participant's trial was ranked with 4.

To assess the ability of sit-to-stand, each participant was seated in a chair (height 43.5 cm) with its straight-back placed next to a wall, and he/she had to raise their arms in front of them at shoulder level during the stand-up tasks. If he/she was able to complete the task one time, an operator asked him/her to produce five sit-to-stand tasks as fast as possible with the arms in the same position as in the first trial. The time of each participant's performance was used for the ranking procedure. If the participant was not able to perform the sit-to-stand task or his/her performance time was more than one minute, his/her score was 0. If the test finished with a time longer than 16.6 seconds, the score was 1. The score assigned to the participant was 2 if his/her performance time ranged from 13.7 to 16.6 seconds. The score 3 was assigned when the test was completed in time range between 11.2 to 13.6 seconds, and if the time was shorter than 11.2 seconds, the score assigned to the participant was 4.

Two evaluation grids (one for a component) were used by the operators for each participant within the time reference values proposed previously. Each operator used a stopwatch to establish the time of each performance, and a camcorder recorded trials of the participants.

Quantitative assessment approach

The quantitative assessment of the abilities' level in standing balance and sit-to-stand was implemented using the Wii Balance Board output measures. The Wii Balance Board is a platform composed of four strain-gauge sensors located under the four corners of its surface. These sensors are able to estimate the vertical component of the ground reaction force (vGRF). The Wii Balance Board was located under the participant's feet during standing balance and sit-to-stand tasks. Data from the four sensors were transferred to a PC via Bluetooth connection using an *ad-hoc* C# application. The frame rate acquisition was set to 50Hz.

The standing balance tests were evaluated using several posturography parameters associated with the sway of the center of pressure (CoP) (Duarte & Freitas, 2010). In Figure 1, the orientation of the reference frame used for side-by-side (a), and for semi-tandem and tandem tests (b) is shown.

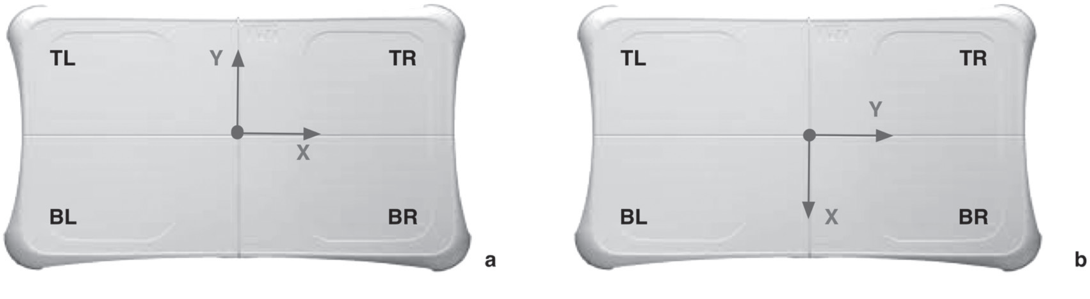

Figure 1. Reference frame of side-by-side test (a), and semi-tandem and full-tandem test (b). TL, TR, BR and BL represent the four strain-gauge sensors: Top-Left, Top-Right, Bottom-Right, and Bottom-Left, respectively.

The coordinates of the CoP were obtained as follows (Clark, et al., 2010):

$$COP_x = \frac{L}{2}\frac{(TR+BR)-(TL+BL)}{F_z}$$

$$COP_y = \frac{W}{2}\frac{(TR+TL)-(BR+BL)}{F_z}$$

where COP_x and COP_y represent the antero-posterior (AP) and lateral-lateral (LL) CoP sway direction, respectively, L and W are the length and the width of the WBB, TL (Top Left), TR (Top Right), BR (Bottom Right), and BL (Bottom Left) are the values extracted from each sensor, and F_z is the vertical component of the ground reaction force estimated as the sum of the four sensors values. According to Clark and colleagues (2010), the CoP signal was filtered using an eight-order Butterworth low-pass filter with cut-off frequency of 12Hz. The posturography parameters (see Table 1) were estimated in agreement with the indication provided by Ruhe and colleagues (Ruhe, Fejer, & Walker, 2010). Considering the low clinician value of the CoP mean position (Schubert, Kirchner, Schmidtbleicher, & Haas, 2012), it was removed from the CoP signals before further analysis.

The assessment of sit-to-stand test was divided into two procedures related to the analysis of the vGRF signal. The first procedure detected the five sit-to-stand tasks using, for each one, the timing characteristics proposed by Zijlstra and colleagues (Zijlstra, Mancini, Lindemann, Chiari, & Zijlstra, 2012). The second provided biomechanical data of each sit-to-stand performance following the event-based approach proposed by Lindemann (Lindemann, et al., 2003). According to Yamamoto

Table 1. Posturography parameters used for assessing the standing balance test

Variable	Code	Dimensionality	Description
Root mean square [cm]	RMS	2D	The root mean square values of the CoP trajectory from the center point.
Sway path [cm]	SP	2D	The total length covered by the CoP trajectory.
Mean velocity [cm/s]	MV	2D	The ratio between the total distance covered by CoP and the duration of the test.
Area [cm^2]	Area	2D	The area covered by the CoP trajectory with a 95% confidence interval.
Sway path A/P [cm]	SP_AP	1D	The sway path length in antero-posterior direction.
Sway path L/L [cm]	SP_ML	1D	The sway path length in lateral-lateral direction.
Mean velocity A/P [cm]	MV_AP	1D	The CoP mean velocities in antero-posterior direction.
Mean velocity L/L [cm]	MV_LL	1D	The CoP mean velocities in lateral-lateral direction.

CoP: center of pressure

Table 2. Biomechanical parameters used for assessing the sit-to-stand test

Variable	Code	Description
Start of standing phase [frame]	T1	Defined as the instant when the vGRF decreased more than 2.5% of the body mass.
Instant of max vGRF [frame]	T2	Located as the point where the vGRF reached the maximum value and it represents the seat-off frame.
Preparation time [seconds]	PreT	Defined as the time between the instants T1 and T2.
Extension of body[*] [frame]	T3	Defined as the point where the vGRF reaches the body mass after decreasing and increasing phases.
Rising phase [s]	StandP	Defined as the interval between T2 and T3
The end of STS task[*] [frame]	T4	Defined as the point where the vGRF value oscillates around ±2.5% of the body mass.
Stabilization phase [s]	StabP	Defined as the time range from T3 until the end of the sit-to-stand task (T4).
Normalized max. vGRF [N/kg]	$vGRF_N$	Defined as the value of vGRF in the T2 frame and normalized for the participant’s body mass.
Overshoot	OS	Defined as the difference value between the max value of vGRF and the body mass.
Incline	IC	Defined as the incline of the vGRF curve from 20 to 90% of the range defined between the T1 and T2 instants.

vGRF: vertical component of the ground reaction force. * The names of the variables or their descriptions were directly related to the indexes proposed by Lindemann et al. (2003).

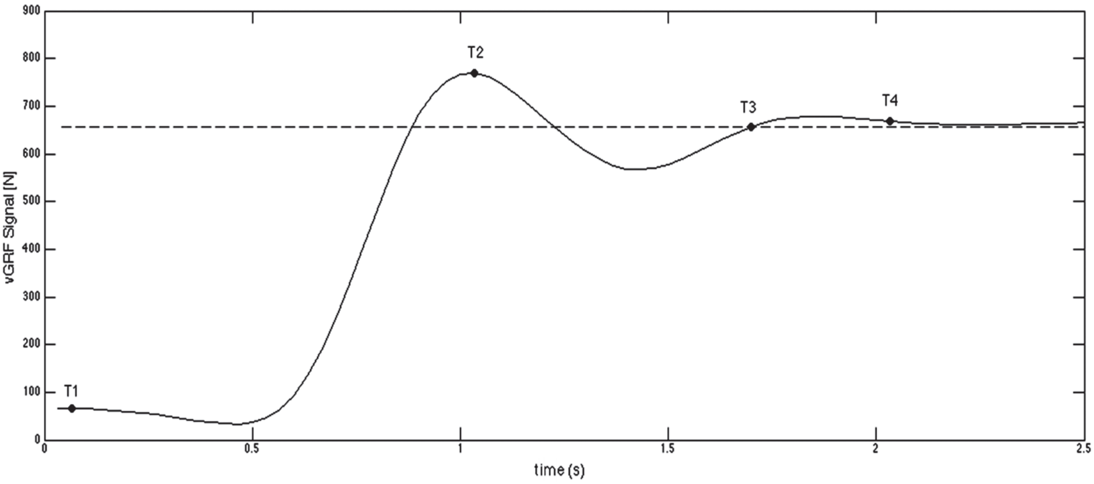

Figure 2. A complete sit-to-stand task signal with the indications used for the definition of the biomechanical parameters described in Table 2. The continuous line represents the vertical component of the ground reaction force signal (vGRF), while the dotted line represents the body mass of the subject. T1 is the start of the standing phase, T2 is the instant of maximum vGRF, T3 represents the frame when the vGRF reaches the body mass, and T4 represents the start of stable posture.

and Matsuzawa (2013), the vGRF signal was not filtered.

In Table 2, the parameters used for the assessment of sit-to-stand task are described, and in Figure 2 a typical curve of vGRF as the function of time is shown.

All the aforementioned analyses were implemented using *ad-hoc* routines developed in the Matlab environment (Matlab, The Mathworks, Inc.).

Statistical analysis

The scores of the SPPB tests were used to define the ability levels of standing balance and sit-to-stand tasks. The inter-observer reliability of clinical test scores was assessed by means of the intraclass correlation coefficient ($ICC_{3,1}$). According to Burdock, Fleiss, and Hardesty (1963), we considered the ICC coefficient high if it was greater than .75.

According to Winter's indications (1995) about the relevance of assessing balance control in side-by-side feet position, this test was here chosen among the SPPB ones as the reference for balance assessment. The data of the standing side-by-side balance test and the mean value of the sit-to-stand tasks for each participant were preliminarily analyzed for accuracy, missing values, univariate and multi-variate normality, and outliers; also, linearity, multi-collinearity, and homoscedasticity assumptions for multivariate analyses were verified (Tabachnick & Fidell, 2007).

Descriptive analysis was reported for all the parameters used to address the participants' abilities in standing balance and sit-to-stand tasks. For each task, between-group differences in these parameters were analyzed by a one-way ANOVA. The r-Pearson correlation coefficient was calculated to identify, for each component, the association between the clinical test results and the parameters estimated from Wii Balance Board output measures. The interpretation of r-Pearson coefficient was based on the Cohen's guidelines (2013).

Linear regression analysis (LRA), with a forward-stepwise procedure, was carried out in order to identify a set of posturography and biomechanical parameters that could explain the association with the clinical test results. In this analysis, we imposed the standing balance and sit-to-stand clinical levels as the independent variables.

A discriminant analysis, with prior probabilities computed from group size, was performed, separately for standing balance and sit-to-stand tasks, aimed to verify if the use of objective measures revealed the same classification of ability levels as the one obtained with the clinical test. If the index Press's Q test was verified (Hair, Anderson, Tatham, & Black, 1998), the cross-validation procedure was carried out by means of the leave-one-out method (Friedman, 1989). The cross-validation procedure was proposed to verify the predictive accuracy of the discriminant model (Sampaio, Janeira, Ibanez, & Lorenzo, 2006).

Results

The clinical assessment was carried out for all thirty-four participants, including the ones who were not able to complete balance or sit-to-stand tasks. The inter-rater reliability level was .93 for the balance tests and .95 for the sit-to-stand test. Considering the assessment results of balance tests, fifteen participants were able to complete the semi-tandem task (level 3 and 4), and nine subjects were able to complete the full-tandem task (level 4). Thirty-two participants were able to complete the side-by-side test (almost level 1). The performances of all the participants in balance and sit-to-stand tasks are shown in Figure 3.

The screening of the side-by-side data revealed that the performances of two participants were not valid (indicated *as not able* in Figure 3), so they were discarded from further statistical analyses. Moreover, we excluded the data of the other two participants because they represented multivariate outliers. The screening of sit-to-stand data revealed that six acquisitions were not valid, and the data of the other three participants were checked as multivariate outliers, so we discarded these participants' data from further analyses as well. The number of participants originally assigned to each performance categories and the valid data after the screening procedure for side-by-side and sit-to-stand tasks are shown in Table 3.

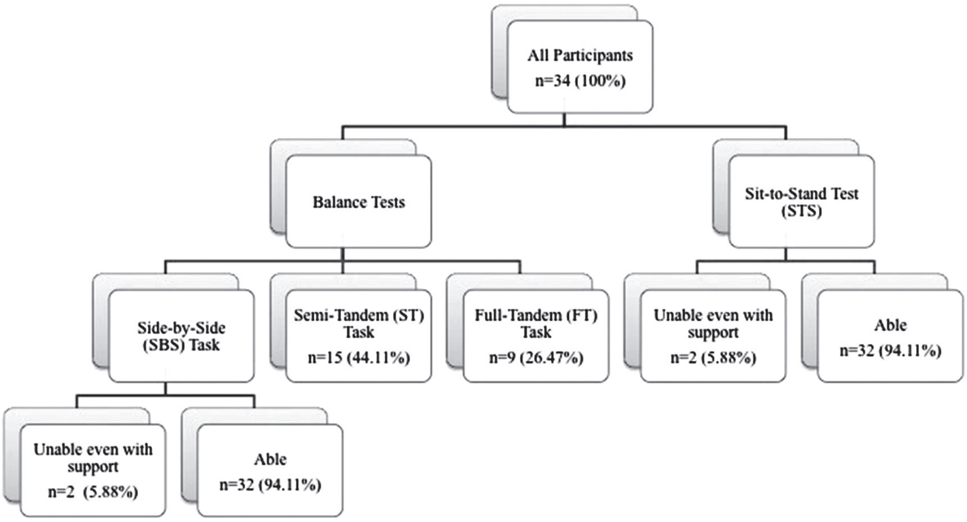

Figure 3. Descriptive results for standing balance and sit-to-stand tests with participants categorized according to their ability level identified by means of SPPB components.

Table 3. The characteristics of the groups for standing balance tests and sit-to-stand test with original and post-screening data

Original data					Post-screening data			
levels	Balance tests: SBS, ST, FT		STS test		Balance test: SBS, ST, FT		STS test	
	n=34		n=34		n=30		n=25	
	n	%	n	%	n	%	n	%
0	2	5.88%	9	26.47%	0	0.00%	0	0.00%
1	15	44.12%	18	52.94%	15	50.00%	18	72.00%
2	0	0.00%	7	20.59%	0	0.00%	7	28.00%
3	6	17.65%	0	0.00%	6	20.00%	0	0.00%
4	9	26.47%	0	0.00%	9	30.00%	0	0.00%

SBS: side-by-side test; ST: semi-tandem test; FT: full-tandem test; STS: sit-to-stand test

*Table 4. Descriptive statistics of side-by-side standing test and ANOVA analysis. The number of participants categorized in each performance level is indicated between brackets (*p<.05)*

CoP-based parameters	Level 1 (15) M (SD)	Level 3 (6) M (SD)	Level 4 (9) M (SD)	ANOVA p
RMS	0.29 (0.11)	0.26 (0.07)	0.20 (0.10)	**2.23***
SP	5.20 (2.10)	5.05 (1.83)	4.63 (2.49)	.378
MV	0.56 (0.22)	0.59 (0.19)	0.50 (0.20)	.366
AREA	0.0035 (0.001)	0.005 (0.001)	0.0031 (0.001)	1.57
SP - A/P	39.73 (16.01)	36.64 (7.96)	33.20 (7.70)	.562
SP - L/L	45.61 (12,42)	44.63(15.01)	37.97 (11.45)	.933
MV - A/P	0.36 (0.18)	0.37 (0.12)	0.34 (0.12)	.105
MV - L/L	0.35 (0.12)	0.38 (0.12)	0.34 (0.16)	.147

SD: standard deviation, ANOVA: analysis of variance, CoP: center of pressure, RMS: CoP root mean square value, SP: sway path, MV: mean velocity, SP_AP: sway path in antero-posterior direction, SP_LL: sway path in lateral-lateral direction, MV_AP: mean velocity in antero-posterior direction, MV_LL: mean velocity in lateral-lateral direction, Area: the area covered by the CoP trajectory.

*Table 5. Descriptive statistics of sit-to-stand test and ANOVA analysis. The number of participants categorized in each performance level is indicated between brackets (*p<.05; **p<.01)*

Spatio-temporal parameters	Level 1 (18) M (SD)	Level 2 (7) M (SD)	ANOVA p
PreT	1.16 (0.24)	1.00 (0.17)	2.54
StandP	0.81 (0.16)	0.77 (0.12)	.332
StabP	0.63 (0.36)	0.37 (0.13)	3.51
$vGRF_N$	1.09 (0.06)	1.22 (0.03)	**27.24****
OS	73.72 (35.91)	120.03 (40.72)	**7.79****
IC	1.54 (0.00)	1.55 (0.00)	3.15

SD: standard deviation, ANOVA: analysis of variance, PreT: preparation time, StandP: standing phase, StabP: stabilization phase, $vGRF_N$: the normalized value of the vertical ground reaction force in the instant T2, OS: overshoot, IC: incline.

In Tables 4 and 5, we report the mean, standard deviation, and ANOVA *F* ratio values for the side-by-side posturography parameters and biomechanical parameters of the sit-to-stand task, respectively.

The RMS was the only posturography parameter that resulted in significant differences among the balance ability levels. The maximum vertical value of the ground reaction force normalized for body mass and the overshoot resulted in statistically significant differences in the performance categories of the sit-to-stand test.

In Tables 6 and 7, we report the results of r-Pearson correlation analysis for side-by-side and sit-to-stand tests, respectively.

As for the side-by-side test, the correlations among posturography parameters and the clinical levels were generally negative and low, WHEREAS the correlations within the posturography parameters were high and statistically significant. The parameters' maximum vertical value of the ground reaction force, normalized for body mass, and the overshoot resulted in moderate and significant correlations with the clinical levels (r=.736 and r=.503 with p<.01 and p<.05, respectively). Both variables correlated with the other biomechanical parameters, except for the preparation time.

To avoid multi-collinearity problems for side-by-side data in linear regression analysis, we composed two sub-groups of variables: RMS, SP, MV_LL, MV_AP and Area were in the first group, while RMS, MV, SP_AP, SP_ML and Area were in the second. The groups contained 1D and 2D parameters, distances and time-dis-tance parameters. As a whole, the significant model obtained from linear regression forward-stepwise analysis had the same characteristics for both aforementioned groups (R=.374, R^2=.140, AdjR^2=.109, ΔR^2=.140, $\Delta F_{1,28}$

*Table 6. Pearson correlation measures between posturography parameters and side-by-side levels (*p<.05, ** p<.01)*

		1	2	3	4	5	6	7	8	9
1	Balance levels	-	-.374*	-.126	-.123	-.200	-.242	-.073	-.051	-.109
2	RMS		-	.698**	.692**	.734**	.593**	.621**	.454*	.533**
3	SP			-	1.00**	.801**	.652**	.950**	.691*	.842**
4	MV				-	.800**	.653**	.950**	.691**	.844**
5	SP_AP					-	.556**	.808**	.432*	.665**
6	SP_ML						-	.475**	.754**	.570**
7	MV_AP							-	.539**	.792**
8	MV_LL								-	.577**
9	Area									-

CoP: center of pressure, RMS: CoP root mean square value, SP: sway path, MV: mean velocity, SP_AP: sway path in antero-posterior direction, SP_LL: sway path in lateral-lateral direction, MV_AP: mean velocity in antero-posterior direction, MV_LL: mean velocity in lateral-lateral direction, Area: the area covered by the CoP trajectory.

*Table 7. Pearson correlation measures between biomechanical parameters and sit-to-stand levels (*p<.05; ** p<.01)*

		1	2	3	4	5	6	7
1	STS Levels	1	-.315	-.119	-.364	.736**	.503*	.347
2	PreT		1	.001	.333	-.110	-.039	-.097
3	StandP			1	.419*	-.586**	-.477*	-.359
4	StabP				1	-.505**	-.507**	-.362
5	$vGRF_N$					1	.880**	.476*
6	OS						1	.632**
7	IC							1

STS Level: sit-to-stand levels, PreT: preparation time, StandP: standing phase, StabP: stabilization phase, vGRFN: the normalized value of the vertical ground reaction force in the instant T2, OS: overshoot, IC: incline.

=4.453, p=.04), with RMS as the only predictor (Beta standardized=-.377, t=-2.185, p=.04).

Linear regression analysis of sit-to-stand tests revealed two significant models, as a whole, with the following characteristics:

- R=.736, R^2=.542, AdjR^2=.522, ΔR^2=.542, $\Delta F_{1,23}$= 27.241, p=.000.
- R=.831, R^2=.691, AdjR^2=.663, ΔR^2=.149, $\Delta F_{1,22}$ =10.618, p=.004.

The predictor of the first model was the maximum vertical value of the ground reaction force normalized for body mass (Beta standardized=.736, t=5.219, p=.000), while of the second the predictors were the maximum vertical value of ground reaction force, normalized for body mass (Beta standardized=.773, t=6.493, p=.000), and the preparation time (Beta standardized=-.388, t=-3.259, p=.003).

The classification procedure of discriminant analysis for the standing balance test revealed that the accuracy of classification rate in respect to the clinical levels was 63.3%. The Press's Q level was 15, and it exceeded the comparison critical value (χ^2=6.63, df=1). The cross-validation procedure revealed that the classification accuracy decreased to 46.7%. The discriminant analysis result for the sit-to-stand test showed that the classification agreement between the clinical levels and the biomechanical parameters was 92.2%. The Press's Q level (17.64) exceeded the comparison critical value, while the classification accuracy after the cross-validation procedure was 88.0%.

Discussion and conclusions

In this work we used a promising low-cost device for assessing balance and mobility proficiency in community-dwelling older people. Purposely, we verified the feasibility of using the Wii Balance Board in order to assess and discriminate the ability levels recognized with a validated clinical test.

The clinical assessment was based on the standing balance and sit-to-stand components of the SPPB test. This test was used for assessing fall risk in elderly people (Murphy, Olson, Protas, & Overby, 2003) and their validity and reliability in community cohorts was recently asserted (Freire, et al., 2012). In respect to this study, the distribution of the participants in standing balance and sit-to-stand levels is partially in agreement with the ones shown in a previous study (Guralnik, et al., 1994) for a bigger sample of participants, but with the same average age.

The Wii Balance Board was used for the objective assessment. To the best of our knowledge, this is the first study that proposes the use of the Wii Balance Board for the assessment of sit-to-stand tasks in community-dwelling older people. In accordance with previous studies (Ruhe, et al., 2010), standing balance was measured with eight posturography parameters related to distance and time-distance characteristics of the CoP time series. The sit-to-stand motor strategy was assessed with several biomechanical indexes discussed in a previous study (Lindemann, et al., 2003).

The participants grouped at the first and second level with the clinical test showed posturography parameters mean values higher than the ones of the third level. According to previous findings about the balance assessment in the elderly (Park, Jung, & Kweon, 2014), the parameters related to the sway in lateral-lateral direction showed more differences among the levels. The mean values of the biomechanical parameters used for assessing the motor strategy of sit-to-stand task were in agreement with the different levels obtained with the clinical test. The data from Table 4 show that the mean values of participants categorized in level 1 are higher for time parameters and lower for kinetic ones; furthermore, the maximum vertical value of the ground reaction force normalized for body mass and the overshoot are significantly different between the levels.

To investigate our first hypothesis, we addressed the relationship between the scores of SPPB components and the objectivity parameters.

In the standing balance test, the r-Pearson correlation analysis showed a low relation between the Wii Balance Board measures and the clinical scores. The RMS correlated with clinical levels in a statistically significant way, while all the other parameters had negative correlation and were not statistically significant. In accordance with a previous study (Nguyen, et al., 2012), the mean velocity was much higher when correlated with the AP than with the ML measures. The low correlation between the two typologies of measures and the high correlation within posturography parameters was in agreement with previous studies (Frykberg, Lindmark, Lanshammar, & Borg, 2007; Nguyen, et al., 2012). The forward-stepwise linear regression analysis yielded one significant model that explains the association between the scores of the clinical test and the posturography parameters. The only predictor proposed in the model was the RMS, which partially explains (14%) the efficacy of the model to defend the clinical test results. These results confirmed that the two approaches measured the balance abilities with different sensitivity (Hughes, Duncan, Rose, Chandler, & Studenski, 1996; Nguyen, et al., 2012).

The association between clinical scores and sit-to-stand measures was generally modest. The maximum vertical value of the ground reaction force, normalized for body mass, and the overshoot were the only measures that had a statistically significant correlation with the clinical results. According to Houck and colleagues (Houck, Kneiss, Bukata, & Puzas, 2011), the maximum vertical value of the ground reaction force normalized for body mass was positive and significantly correlated with va-lidated clinical measures. The regression analy-sis described the association between the clinical scores and the biomechanical parameters with two different significant models. The second model explains about 70% of the relation between the two assessment approaches. This model had two predictors: the maximum vertical value of the ground reaction force normalized for body mass and the preparation time, that have just been indicated in literature as good descriptors of sit-to-stand performance in elderly populations (Chang, Leung, Liou, & Tsai, 2010; Chang, Leung, & Liou, 2013). Different levels of association between the clinical results and the Wii Balance Board output measurements partially confirmed our hypothesis about the relation between the two approaches, but they seem to outline that the balance and mobility performance required complex integration and coordination of multiple body systems (Horak, 1997) and their assessment needed the integration of multiaims tools, as partially proposed by others (Nguyen, et al., 2012).

Our hypothesis about the feasibility of using the Wii Balance Board output measurements to predict the ability levels has been verified with discriminant analysis results. The classification rates of the original and the cross-validated procedures showed a modest level of accuracy for standing balance test and a high level for the sit-to-stand test (Tabachnick & Fidell, 2007). Furthermore, the results of Press's Q statistics and cross-validation procedures support the models' accuracy to predict the classification above what has been expected by chance.

The results of this work have some limitations. First, the sample was not big enough, therefore the results could not be generalized to all elderly people living in the community. Moreover, we did not provide a comparison for gender and for previous fall experiences because the characteristics of our participants were not useful to address the role of these factors. Future cross-sectional research should involve more participants to permit us to investigate the relation of the aforementioned elements with our models in greater detail. Gait performance and sway of the center of mass will be accounted for in the balance and mobility assessment of elderly by means of other low-cost devices, such as the Microsoft Kinect and inertial-magnetic motion sensors. The use of the marker-less analysis systems (i.e. Microsoft Kinect) and of the motion sensors has been encouraged for supporting the clinical balance assessment procedures.

This study advises the availability of new resources for improving the balance assessment in elderly people. In this respect, considering that the use of WBB has also been proposed for balance training activities (Young, et al., 2011), the medical practitioners should use clinical tests to define the levels of balance ability, and Wii Balance Board outcomes to assess small postural changes expected during and after a training period.

In conclusion, we can outline the following points. A low level of agreement between the Wii Balance Board measures and the clinical results in standing balance assessment suggested that the device is not ready to be used as a standalone assessment method. However, the integration with clinical tests is suggested because these two approaches could complement each other, measuring different aspects of balance. The use of Wii Balance Board for assessing sit-to-stand ability levels in the elderly population revealed promising findings, and future investigations on the validity and reliability of this device seem warranted.

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