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Original Article

Reliability and validity of the mCTSIB dynamic platform test to assess balance in a population of older women living in the community

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Abstract

Objectives: Test the reliability and validity of the modified Clinical test of Sensory Interaction in Balance (mCTSIB) of the Balance Platform Biodex Balance System (BBS) in a female community dwelling population. **Method:** 100 women over 65 years community dwellers mean age 71.8 (SD±6, ranging from 65 to 91) years, were examined using the posturography modified Clinical test of Sensory Interaction on Balance (mCTSIB) protocol of the Biodex Balance system SD and the Greek Mini-Best Test (miniBESTest-GR) to assess concurrent validity, with 24 undergoing a second measurement after one week to test the reliability of the method. **Results:** The m-CTSIB-"Composite Score" test was significantly and positively correlated with the mini-BESTest-GR (r= -0.652, p<0.001) indicating good validity properties. The test-retest reliability was measured using the intra-class correlation coefficient (ICC) using a two-way mixed-effects absolute-agreement single-measurement model, among the two measurements of mCTSIB test (test-retest). No statistical difference was found between the two samples (N1=100, N2=24, t= -1.755, df=122, p=0.08). ICC estimates as 0.628 with 95% confident interval=0.31-0.82. **Conclusion:** The mCTSIB test from the BBS has a moderate validity and reliability to evaluate balance in elderly women living in the community and can be used as a screening tool.

Keywords: Aging, Balance, Dynamic Platform, mCTSIB, miniBEST Test

Introduction

Balance meaning the ability to maintain the center of gravity inside the base of support, is fundamental for the mobility and overall function regardless of age. Postural stability at the other hand even thought is usually used synonymously with balance is defined as the ability to maintain an upright posture during quiet stance; or the recovery of balance following external perturbation or displacement of the support surface during dynamic conditions[1]. Postural control is a complex goal to achieve because it needs coordination and integration of sensory information's such as vestibular, visual, proprioceptive and hearing, as well as inputs from the autonomic systems, that arrive at many levels of the central nervous system where they are integrated and compared to memory (spatial maps and previously learned responses). With advancing age, changes related to aging *per se*, and those associated with diseases and their treatments, can affect the integrity and function of all the above-mentioned systems, at the same time plasticity and repair are impaired and as a result balance can be affected and induce to a fall[2].

Balance evaluation is of great importance not only for diagnostic but also for treatment purposes in this vulnerable age group. Anamnesis and physical examination by itself can detect changes and flaws in balance, but the accuracy is limited and highly dependent on the examiner[3]. Further information's can be provided by clinical tests that evaluate the patient's ability to maintain balance.

Moreover, as there is a high dependence on the examiner's abilities and the familiarization with the scale, interrater variability of the scoring might be detected. Nevertheless,

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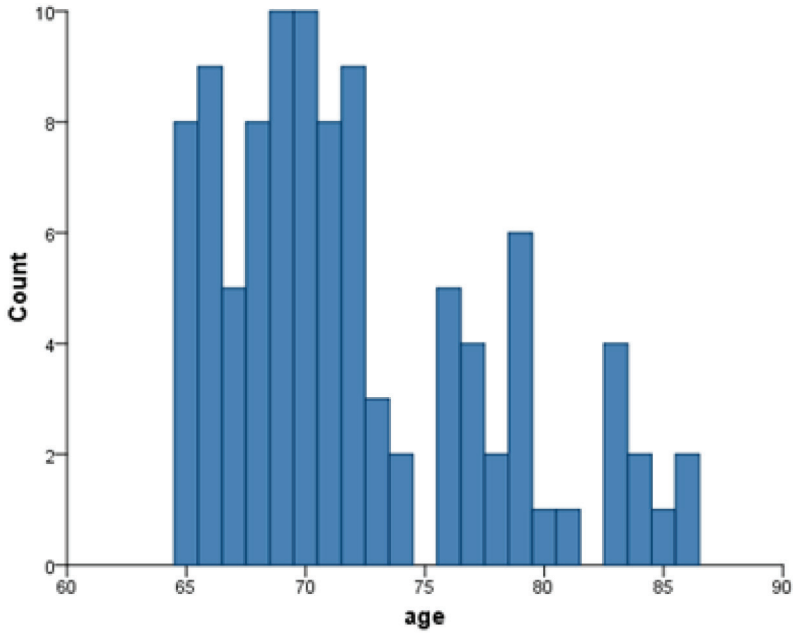

Figure 1. Age distribution of the women included in the study.

these kinds of clinical examinations are widely used in clinical practice (e.g. Berg Balance Test, miniBEST test).

In addition to the aforementioned evaluations, posturographic systems are commonplace in clinical settings. These provide computerized instrumented tools, operating in two modes, while postural control is assessed: static, when the participant is asked to maintain stance in a relatively unperturbed state[4], and dynamic, when the participant is challenged with experimentally induced perturbations (e.g. by using movable platform)[5]. These systems have the advantage of being more subjective during the evaluation process and have continuous values of estimation, but still most of them have no cut off points[6]. Two types of posturographic systems are commonly used: the ones that operate through a force platform (measures postural sway determined by the movement of the center of pressure (CoP) of the ground reaction force) whilst others like the BBS operate through a circular platform. The circular platform system is free to movement in the anterio-posterior and mediolateral axis simultaneously and it is possible to adjust the stability of the platform by varying the resistance force applied to it through springs located at the associated perimeter of the balance platform. Rather than measuring the deviation of the CoP this multiaxial device measures the degree of tilt about each axis[7].

Older women are the most frequent assessed population for postural disorders due to their propensity for falls. There are some studies evaluating the BBS tests in various parameters such as the intraobserver and interobserver reliability, test-retest reliability, and repeatability, in various populations[8-12] with good results. Only one study tested the reliability but not the validity of the modified Clinical Test of Sensory Interaction in Balance (mCTSIB) protocol of the BBS, but in healthy adults of both sexes with a wide age range[12]. The aim of this study was to evaluate the reliability and validity of the instrumental mCTSIB test of the BBS in a population of older women living in the community. For the concurrent validity evaluation, we compared the computerized instrumented test to the mini-BESTest.

Materials and methods

Participants

One hundred female participants (mean age 71.8 SD±6, range=65-91) years (Figure 1) were recruited from our outpatient fall-sarcopenia-osteoporosis clinic over a one year period (from November 2017 to October 2018) to test concurrent validity and in 24 cases (random sample selected) test-retest reliability was evaluated. The Ethics Committee of the Hospital approved the protocol, and informed written consent was obtained from all participants prior to taking part in the study.

The inclusion criteria included the following: being female older than 65 years of age, and the status of community dwelling. The exclusion criteria included: the inability to fully understand the instructions given regarding the performance of the associated tasks [listed in both the mCTSIB and mini-BESTest], inability to maintain independently upright position or critical weight-bearing limitations (including recent lower limb fracture or arthroplasty - within the last three months. Finally, individuals presenting more than 2 cm leg length discrepancy were excluded from the study.

Table 1. Clinical characteristic of the participants.

Clinical conditions of the participants	Total no of participants with the condition	No of fallers with the condition
High Blood Pressure	52	10
Diabetes Mellitus	43	6
Anxiety disorder or Depression	23	9
Osteoporosis	32	9
Osteoarthritis	19	3
Peripheral neuropathy	1	
Fragility Fracture	38	12
Hyperlipidemia	52	10
Chronic Obstructive Pulmonary Disease	6	
Thyroid Disease	20	7
Rheumatoid Arthritis	7	3
Cancer	8	4
Hyperuricemia	7	2
Gastrointestinal disease	16	3
Psychosis	2	
Angiopathy	9	
Spinal Disorders	4	
Cataract	12	6
Restless leg Syndrome	2	
Major limb Surgery	12	6
Extrapyramidal Syndromes	1	
Chronic Kidney Disease	2	2
TBC	1	1
Autoimmune Disorders	3	
Pneumonic Hypertension	1	
Hematological Diseases	1	
More than 4 drugs per day	45	17
Drugs with CNS effects	33	13

Table 1 shows the number of participants with clinical characteristics collected via patient's medical history. In addition, the clinical diagnosis and prescribed medications are also reported in the table. The number of medications (>4 pharmaceutical substances) per day as well as the use of substances having an impact on the Central Nervous System - due to the link of these factors with balances disorders.

With a given number of participants equal to 100 and effect size 0.3 as significant at the 5% level, the differential power of the tests was calculated to be 84%.

Clinical assessment

All participants were tested the same day in both the mCTSIB in the Biodex platform and mini-BESTest, after a thorough clinical examination by the same medical doctor. The testing room had an average temperature of 22°C and normal humidity levels. The participants were asked to remove their shoes (in order to avoid any unfit shoe interference and hygiene concerns) and to enable better proprioceptive evaluation. The testing procedure was explained to participants and they were given the opportunity to ask questions and seek any clarification. Only one trial was performed before the main evaluation to avoid interference with the final results. Both tests were performed by the same experienced Physical Therapist (PT), who was trained to carry out and grade correctly the mini-BESTest.

mCTSIB test of the Biodex Balance platform SD

The Biodex Balance platform (BBS) is as mentioned before a circular platform that measures the degree of tilt in each axis rather than measuring the deviation of the CoP. The platform tilts-up to 20° in any direction with 12 stability levels (12 being the most stable and 1 being the least) according to spring resistance with each resistance lasting approximately 3,75 sec. The calculations of the mediolateral stability index (MLSI), the anteroposterior stability index (APSI) and therefore the overall stability index (OSI) derives from the summation of the degrees of tilt calculated in the

Table 2. the mCTSIB test.

Surface	Visual	Input
Firm	Eyes open	Baseline condition: Input is visual, vestibular, and somatosensory.
	Eyes closed	Evaluates vestibular and somatosensory inputs.
Dynamic	Eyes open	Evaluates vestibular interaction with visual input.
	Eyes closed	Evaluates vestibular input.

AP and ML axis[7]. The device includes several instrumented tests for balance evaluation including the mCTSIB test. This is a modified version of the original CTSIB that eliminate the visual conflict domain (see Table 2)[10]. It consists of four conditions: Condition 1 - Eyes Open Firm Surface EOFS, is characterized as a baseline condition where the goal is to maintain un upright position while being in a firm surface. That particular condition incorporates visual, vestibular and somatosensory inputs. Condition 2 - Eyes Closed Firm Surface ECFS, eliminates the visual input in order to evaluate vestibular and somatosensory inputs. Condition 3 - Eyes Open on a Dynamic Surface like Foam EOFoS, evaluation of the interaction between visual and vestibular input. Condition 4 - Eyes Closed on Dynamic Surface Foam ECFoS, evaluation of the singular vestibular inputs, and the overall Composite Score or Sway Index (CS or SI).

In order to measure conditions 3 and 4, we need to simulate a more dynamic condition, to this purpose a cushion must be inserted on top of the platform device. The cushion is part of the device equipment and has the same marking as the firm surface, for correct foot placement.

Whenever the patient could not follow the placements of the foot suggested by the device, because it felt uncomfortable, we advised them to find the most comfortable and at the same time the most stable position by keeping the feet apart and maintaining the dot (a black dot that indicates the patients displacements in the device) in the center of the board of the devices screen. The position preferred was registered for future reference[13]. Each evaluated condition of the mCTSIB test lasted for 30 seconds and after 10 seconds of rest the next condition was tested. The examiner inputted the personal data of the patient into the software, along with information about age and height. With the height and age of the individual entered, the device could properly measure the displacements of the center of gravity located at approximately 55% of human height[11].

The evaluation is based on scoring the number of displacements of the 30''second duration and 10'' second intervals. There was a recording for every condition and the Composite Score (CS). The CS is defined as the standard deviation of the stability index with the index representing situations around the zero point that was established when the platform was most stable (level 12), with a higher CS score representing greater instability. The durations of the test lasted 10 minutes per study participant. The test measures how well a patient compensates with sensory inputs.

Mini-BESTest

Participants, following a short break to recover, were then tested with the mini-BESTest. We used the Greek translation of the scale mini-BESTest-GR[15] wich has proven reliability and validity and also cross-cultural adaptation. The Mini-BESTest, the short form of the BEST test (created with the aid of factor analysis and Rasch analysis), is a rather comprehensive clinical scale for balance evaluation. It comprises four balance spectrums such as transitions and anticipatory postural adjustments, postural responses to the loss of balance, sensory orientation while standing on a compliant or inclined base of support, and dynamic stability during gait. That way a large variety of tasks are covered such as dynamic body stability, transfers, gait, variation of support surfaces and of visual conditions, obstacle negotiation, reactions to external forces, and performance during dual-tasking etc. The several tasks are scored from 0 (unable to perform or help is required) to 2 (normal performance). The maximum total score is 28. A wide range of measurement properties were investigated, demonstrating that the scale shows good content coverage and metric quality. The test is suitable in all metrics for balance evaluation in the older people[14]. It can be administered in 15 min (is the average time needed to complete the test), and requires special equipment (chair with standard measures, stopwatch, particular type of foam and shoe boxes), whereas the rater familiarization with the scale is an advantage. For the performance of the miniBEST test we used the recommended equipment by Horak et al. a standard chair with armrests, a 10-cm-thick Tempur® foam, a stopwatch, an inclined surface (10°), and two shoe-boxes[16].

The 24 women tested for the reliability of the tool (mCTSIB) were invited to repeat the mCTSIB test after 7 days. The second measurement was only for the mCTSIB test. The protocol used was as mentioned above, in the description of the measurement, and the foot positioning in the mCTSIB test platform was the same as the first measurement.

Results

All data were presented as mean ± standard deviation (mean±SD), and statistical significance was set at $p \leq 0.05$. Statistical analysis was performed with SPSS (version 25.0, SPSS for Windows, Chicago, SPSS Inc.)

Concurrent validity was investigated, in n=100 older women participation in the study, was calculated by using Spearman's

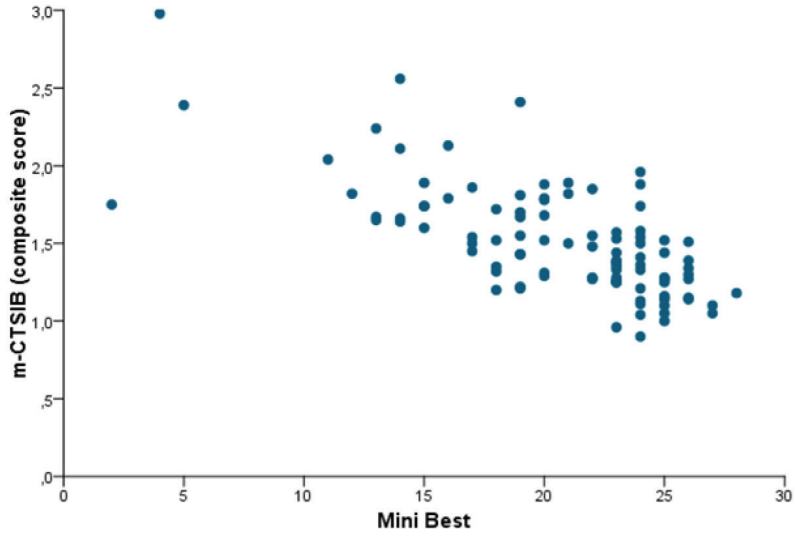

Figure 2. Scatter-plot of correlation coefficient between scores of m-CTSIB-"Composite Score" and Mini-BESTest-GR.

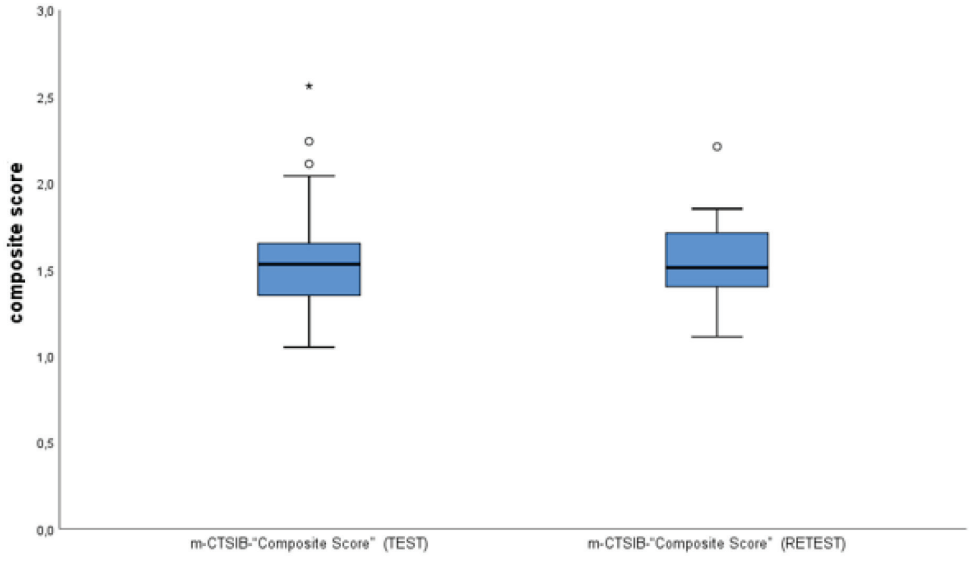

Figure 3. Boxplot of m-CTSIB-"Composite Score" test score (test-retest).

correlation coefficient between scores of Modified Clinical Test of Sensory Interaction in Balance (mCTSIB test) and Mini-BESTest-GR. The m-CTSIB-"Composite Score" test was significantly and positively correlated with the mini-BESTest-GR (r= -0.652, p<0.001) indicating good validity properties (Figure 2). The mCTSIB "Eyes Open, Firm Surface" test was significantly and positively correlated with the mini-BESTest-GR (r= -0.309, p=0.002). The m-CTSIB-"Eyes Closed, Firm Surface" test was significantly and positively correlated with the mini-BESTest-GR (r= -0.239, p=0.017). The m-CTSIB-"Eyes Open, Foam Surface" test was significantly and positively correlated with the mini-BESTest-GR (r= -0.605, p<0.001). The m-CTSIB-"Eyes Closed, Foam Surface" test was significantly and positively correlated with the mini-BESTest-GR (r= -0.441, p<0.001). Values between 0.0-0.25 as little if any correlation, 0.26-0.49 low correlation, 0.50-0.69 moderate correlation, 0.70-0.89 high correlation, and 0.90-1.00 very high correlation[17].

The test-retest reliability was measured, in 24 women (a random sample of the 100 women), using the intra-class correlation coefficient (ICC) using two-way mixed-effects absolute-agreement single-measurement model, among

Table 3. Mean and Median.

	Mean	Median	Standard Deviation	Count
Mini Best	20,59	22,00	4,98	100
m-CTSIB (composite score)	1,52	1,45	,36	100
Eyes Open, Firm Surface	,58	,53	,27	100
Eyes Closed, Firm Surface	1,03	,91	,43	100
Eyes Open, Foam Surface	1,17	1,00	,45	100
Eyes Closed, Foam Surface	3,28	3,12	,92	100

Table 4. Tests of Normality.

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Mini Best	,173	99	,000	,890	99	,000
m-CTSIB (composite score)	,099	99	,018	,927	99	,000
Eyes Open, Firm Surface	,152	99	,000	,874	99	,000
Eyes Closed, Firm Surface	,137	99	,000	,874	99	,000
Eyes Open, Foam Surface	,161	99	,000	,829	99	,000
Eyes Closed, Foam Surface	,136	99	,000	,911	99	,000
[a]. Lilliefors Significance Correction						

the two measurements of mCTSIB test (test-retest). The mean age of the 24 women was 74.3 (SD±7.3, range= 66-87) years. No statistical difference was found between the two samples (N1=100, N2=24, t= -1.755, df=122, p=0.08). ICC estimates as 0.628 with 95% confident interval ranging from 0.31-0.82 (Figure 3). Values less than 0.5 are indicative of poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values greater than 0.90 indicate excellent reliability.

We have also calculated mean and median values and performed a normality test to estimate the possible generalization of the findings to the general population (Tables 3 and 4).

Discussion

This is the first study to address test-retest reliability, and concurrent validity of the mCTSIB Biodex Balance System in a sample of older women (65 years of age or older) living in the community both fallers and no fallers, the sample size had a differential power of the tests calculated to be 99.8%, very high. Our results suggest that the reliability in this population is moderate with an ICC of 0.628 with 0.95% confidence interval=0.31-0.82. Reliability estimates with ICC over 0.9 would be ideal, but this appears to be an unrealistic benchmark for a test assessing something as complex as balance[12]. We also found a moderate correlation between the miniBEST test and the mCTSIB and as such we can recommend that the mCTSIB can be used as a first line rapid assessment, for postural evaluation. Its advantages being that is not dependent on rater's estimates, gives a continuum of estimates in comparison with the clinical tests, and is quick to administer (less than 10 min).

Test retest reliability is a fundamental principal component of psychometric testing. However, in the literature there are few data about the reliability and concurrent validity of the instrumented tests. For the BBS platform we were able to find the following studies examining the reliability of all the platform's protocols. It should be noted that all of the following protocols evaluated the reliability of the BBS platform for other protocols but none for the mCTSIB, because it was not part of the old platform's tests. Schmitz et al[18] evaluated the test-retest reliability of the Single Leg test of the BBS, in 19 healthy university students (8 male and 11 female) with a decreased stability protocol (platform from 8 to 1 over 30 sec, in the BBS stability decreases from level 12 to level 1). They found an intratester ICC ranged from 0.82 to 0.43 for stability scores and an intratester 0.7 to 0.42 it a 7 days trial, with the Overall Stability Index (OSI) being the most reliable ranging from 0.82 το 0.7 Hinman[10] studied the reliability of the platform test with 4 studies; Study 1 with 50 subjects (31 women and 19 men) between 18 and 65 were tested for 30 sec with 2 different stability levels and eyes open; Study 2 with 50 subjects (37 women and 13 men) between 21 and 52 were tested for 30 sec with stability level 6 (stability

levels from 12 to 1 less) and different visual conditions, eyes open looking straight ahead, eyes open with visual feedback and eyes closed; Study 3 with 79 subjects (47 women and 32 men) between 65 and 92 were tested for 30 sec with stability level 7 and eyes open receiving visual feedback with both hard-soles shoes and soft-soled shoes; and Study 4 with 44 subjects (37 women and 7 men) between 21 and 50 were tested for the Limit of Stability protocol and two different visual conditions, visual feedback and visual impairment. Also, the stability level was 6 and the subjects were asked to move the platform in a linear and circular way. The ICCs for the first 3 static studies ranged from 0.44 to 0.89, and for the most challenging study 4 from 0.77 to 0.89. The easiest condition (ie the most stable) demonstrates poorer test-retest reliability. In the study of Karimi et al [19] 23 male participants with low back pain (LBP) and a control group of 20 age matched healthy males the ICC of the static test of BBS were the highest for those with LBP ranging from 0.91 to 0.95 and controls from 0.88 to 0.96. In the study of Pincivero, 20 college students performed 3 test trials with bilateral limb stance, single dominant and non-dominant in 2 stability levels with ICC varying from 0.62-0.95[20]. Cachupe et all.[21] tested the reliability of BBS in 20 active students college-age 10 men and 10 women average age 27, 30% of which had a previous ankle sprain in a single leg test 8 trials until fatigued and replication with 27 athletes 10 males and 17 females the ICC ranged from 0.76 to 0.93. Arifin et al., 2013[1] with 20 healthy University Students in 7 days interval found ICC For OSI Anteroposterior Stability Index (APSI) and Mediolateral Stability Index (MLSI) from 0.85, 0.78, and 0.84 during static conditions and 0.77, 0.77, and 0.65 for dynamic. All of studies mentioned above had small numbers of participants, with wide age ranges and different test protocols (e.g. stability levels, physical conditions, interval times, and number of trials). Summarizing, the BBS tests demonstrate good to moderate reliability properties, in various populations and study conditions.

For the mCTSIB in posturography only two studies were found from Kim et al.,[22] on test retest reliability with the Fall Risk Assessment System, not the BBS, in 38 community dwelling older adults, measured with a week apart. ICC of the CS was 0.79 with poor to moderate reliability for the other four categories. This is a study performed with a different posturographic platform and a small size of community dwelling older adults of both sexes, that limits the strength of the results.

Dawson[12] examined the reliability of BBS mCTSIB in a convenience sample of 105 healthy adult 77 females 28 males found a CS of ICC of 0.75 of the mCTSIB CS, and of the LOS test 0.5, with poor reliability for Condition 1 (eyes open on firm surface). Even though is a study performed in the same platform, the participants are from a wide range of age with a mean age of 24,5.

The moderate reliability values found, aligns with other studies that tested the various BBS protocols, as well as the study of Dawson that assessed the same BBS protocol. At the same moderate range of the ICC (ICC=0,75) ranges the reliability of the clinical mCTSIB test[23]. Although our study only evaluated people over 65 years of age, still postural responses, and disease burden can vary substantially every decade, explaining the moderate reliability. Important variables for the performance in older people, are fear of falling and in general cognitive and emotional factors that can influence results and overall performance[5]. The moderate reliability of ICC in balance tests is also affected by the degree of measurement "noise" (an error or undesired random disturbance of a useful information signal), which is assumed to vary across trials and visits, and the magnitude of the true signal, also affected by the patient's psychological and physiological status, and the learning effect by the repeated administration of the test. Even tests with lower reliability indices, as demonstrated, can still be of clinical value[24]. Variability of the postural responses is present not only in older people but also in younger adults without postural impairments and that can negatively affect the test-retest reliability[25].

In our study the Composite Score (CS) of the measure was significantly and positively associated with the mini-BESTest and proved the concurrent validity of the assessment. Even though the association was moderate (r=0,652) it is still a positive correlation. From the four subgroups of items (see 'Condition' column in Table 2) the best correlation was with the Eyes Open Foam Surface(r=0,605). In this condition, the result of the measurement is largely dependent on the integration between vision and muscular function, deep sensation being disturbed by the unstable surface, the vestibular stimuli act secondarily. The other three tasks had inferior values of association. We deduce that the task Eyes open Firm Surface, being a basic condition were all sensations provide stimuli, is easy even for older women that have balance disorders and score poorly in the miniBEST. On the other hand, the task where the eyes are closed (EOFS, EOFoS) are challenging for older women even though they do not present any balance deficits. From all the above we can conclude that visual stimuli have a great contribution to postural control in older people.

The mCTSIBtest seems to be a reliable and valid tool for balance screening in older woman living in the community even with resultant association in a moderate level. The evaluation procedure itself is easy and repeatable and takes 10 min, while the rater does not need any expertise. This is the first study that compares the mCTSIB of the BBS and the mini-BESTest. The two tests have a good correlation and they can be used as complementary in the process of postural control evaluation. Equally important, the mCTSIB, can identify which part of the sensory system is impaired, whereas the mini-BESTest cannot do so. Comparing the mCSTIB and the miniBESTest, we see that the mCTSIB is a quick test and does not need expertise or training to be correctly performed, making it really valuable in the increasingly busy and complex clinical environment.

There are also limitations of the study that we need to address. The first limitation is that although mCTSIB gives an overall balance estimate, it does not consist of different

balance domain and does not differentiate between static and dynamic balance. The structure of the test does not allow for a more detailed analysis of the various possible disruptions. When a postural deficit is detected then a comprehensive assessment is needed to reveal the deficits and help in organizing the best approach to address them. The second limitation is that the test scores were not normally distributed requiring the use of non-parametrical tests that limits somewhat our ability to generalize the study findings to the wider population (Table 3). A third limitation is that it appears that the test-retest reliability of posturographic measures is highly dependent on the type of measure; age and disease conditions of the subjects; and the difficulty of the balance task involved. To reduce inter-subject variability, it is important to select homogeneous groups. For example, including subjects who differ widely in age and clinical characteristics may introduce extra variability because balance reactions change substantially with ageing[5,6]. Furthermore, gender differences were not addressed by the present study, we have shown validity and reliability of the test in the female elder population living in the community, and we do not know the extent to which these results equally apply to the population of older men living in the community. In short the population in study came from only one facility making it a convenience sample (rather than a random sample). Thus, further studies are needed to evaluate older people living in facilities or nursing homes. In terms of the device itself, the limit to its extended use is the acquisition cost. The posturographic systems are quick, standardized and require little expertise in operating but these comes with a price that clinical tests performed with little or no equipment have not. Further studies are needed to create the reference values and cut-off limits of the protocols of the device to correctly report the findings.

Conclusion

Test retest reliability and validity of the mCTSIB test of the BBS SD is within the moderate range but still of clinical value as an early detection test for postural instability or a complementary test of the miniBEST test for the same purpose in an female elderly population living in the community.

References

1. Arifin N, Osman N, Abas W. Intrarater Test-Retest Reliability of Static and Dynamic Stability Indexes Measurement Using the Biodex Stability System During Unilateral Stance. Journal of Applied Biomechanics 2014;30(2):300-304.
2. Nevitt M. Risk Factors for Recurrent Nonsyncopal Falls. JAMA 1989;261(18):2663.
3. Visser J, Carpenter M, van der Kooij H, Bloem B. The clinical utility of posturography. Clinical Neurophysiology 2008;119(11):2424-2436.
4. Kuo A, Speers R, Peterka R, Horak F. Effect of altered sensory conditions on multivariate descriptors of human postural sway. Experimental Brain Research 1998;122(2):185-195.
5. Allum J, Carpenter M, Honegger F, Adkin A, Bloem B. Age-dependent variations in the directional sensitivity of balance corrections and compensatory arm movements in man. The Journal of Physiology 2002; 542(2):643-663.
6. Visser J, Carpenter M, van der Kooij H, Bloem B. The clinical utility of posturography. Clinical Neurophysiology 2008;119(11):2424-2436.
7. Biodex Balance System operation and service manual #950-444. Shirley; Biodex Medical Systems; 2009.
8. Parraca J, Olivares P, Carbonell-Baeza A, Aparicio V, Adsuar J, Gusi N. Test-Retest reliability of Biodex Balance SD on physically active old people. Journal of Human Sport and Exercise 2011;6(2):444-451.
9. Wendy J.C. Cachupe, Bethany Shifflett, Leamor Kahanov & Emily H. Wughalter (2001) Reliability of Biodex Balance System Measures, Measurement in Physical Education and Exercise Science, 5:2, 97-108.
10. Hinman M. Factors Affecting Reliability of the Biodex Balance System: A Summary of Four Studies. Journal of Sport Rehabilitation 2000;9(3):240-252.
11. Fedorowicz J, Bielińska M, Olszewski J. Posturography studies in patients with central and mixed vertigo Summary. Otolaryngologia Polska 2018;72(3):6-11.
12. Dawson N, Dzurino D, Karleskint M, Tucker J. Examining the reliability, correlation, and validity of commonly used assessment tools to measure balance. Health Science Reports 2018;1(12):e98.
13. Pagnacco G, Oggero E, Carrick FR. Repeatability of posturographic measures of the mctsib static balance tests a preliminary investigation. Biomedical Sciences Instrumentation 2008;44:41e46.
14. Franchignoni F, Horak F, Godi M, Nardone A, Giordano A. Using psychometric techniques to improve the Balance Evaluation Systems Test: the mini-BESTest. Journal of Rehabilitation Medicine 2010;42(4):323-331.
15. Sofia L. Cross Cultural Adaptation of Berg Balance Scale in Greek for Various Balance Impairments. Physical Medicine, Rehabilitation & Disabilities 2016;2(1):1-13.
16. Bergström M, Lenholm E, Franzén E. Translation and validation of the Swedish version of the mini-BESTest in subjects with Parkinson's disease or stroke: A pilot study. Physiotherapy Theory and Practice 2012; 28(7):509-514.
17. Koo T, Li M. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. Journal of Chiropractic Medicine 2016; 15(2):155-163.
18. Schmitz R, Arnold B. Intertester and Intratester Reliability of a Dynamic Balance Protocol Using the Biodex Stability System. Journal of Sport Rehabilitation 1998;7(2):95-101.

19. Karimi N, Ebrahimi I, Kahrizi S, Torkaman G. Evaluation of postural balance using the biodex balance system in subjects with and without low back pain. Pakistan Journal of Medical Sciences 2008;24(3):372-7.
20. Pincivero DM, Lephart SM, Henry TJ. Learning effects and reliability of the Biodex Stability System. J Athl Training 1995; 30(35).
21. Cachupe WJC, Shifflett B, Kahanov L, Wughalter EH. Reliability of Biodex Balance System measures. Meas Phys Educ Exerc Sci 2001;5:97-108.
22. Kim M, Kim S, Won C. Test-retest Reliability and Sensitivity to Change of a New Fall Risk Assessment System: A Pilot Study. Annals of Geriatric Medicine and Research 2018;22(2):80-87.
23. Cohen H, Blatchly C, Gombash L. A Study of the Clinical Test of Sensory Interaction and Balance. Physical Therapy 1993;73(6):346-351.
24. Eckner J, Kutcher J, Richardson J. Between-Seasons Test-Retest Reliability of Clinically Measured Reaction Time in National Collegiate Athletic Association Division I Athletes. Journal of Athletic Training 2011; 46(4):409-414.
25. Geurts AC, Nienhuis B, Mulder TW. Intrasubject variability of selected force-platform parameters in the quantification of postural control. Arch Phys Med Rehabil 1993;74:1144-1150.